Population Dynamics After Wildfires in Sagebrush Grasslands

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Highlight: Population dynamics of herbaceous and shrub species were investigated in big sagebrush/Thurber needlegrass communities burned in wildfires. The sites burned are representative of extensive areas of degraded rangelands in the central Great Basin. Herbaceous succession after wildfires in these communities is dominated by the dynamics of populations of the alien annual grass downy brome. Downy brome caryopses are greatly reduced by most large wildfires, but the plants originating from surviving downy brome caryopses respond dynamically to the released environmental potential. The response may include hybridization and recombination. The result is a purge of native annual species from the community and the failure of seedlings of native perennial grass species to become established. Root and crown sprouting of the native shrubs, green rabbitbrush and horsebrush, occurs after the wildfire has killed the dominant big sagebrush. Green rabbitbrush sprouts produce abundant achenes, which readily germinate and grow. The reestablishment of downy brome dominance predisposes the vegetation to recurring wildfires and cyclic environmental degradation.

Our purpose was to investigate plant population dynamics in big sagebrush (*Artemisia tridentata*)/Thurber needlegrass (*Stipa thurberiana*) communities burned in wildfires.

Attrition by livestock grazing may annually influence more acres, but burning by wildfires as a catastrophic stand renewal process is the determinant force shaping the future vegetation of the sagebrush/grasslands in the Great Basin. Burning triggers the population dynamics that are the subject of this investigation.

The incidence and consequence of burning in pristine sagebrush/grasslands are controversial (Daubenmire 1970). It is difficult to reconstruct chronologies for recurrence of wildfires in this type of vegetation because there are no trees to fire-scar. Evidence from woodlands associated with sagebrush/grasslands indicated that wildfires recurred at regular intervals (Burkhardt and Tisdale 1976). Before the influence of European man, the average frequency of fire across con-

tiguous units of sagebrush/grass communities in northern Yellowstone National Park was 32 to 70 years (Houston 1973). Within a large general area, however, some kind of fire occurred at least every 17 to 41 years. Wildfires have been recognized as a factor determining plant succession on degraded sagebrush/grasslands since the arrival of European man in the intermountain west (Pickford 1932).

The dominant shrub characterizing the landscape, big sagebrush, does not sprout from the crown or roots following burning and, therefore, is temporarily eliminated from the community (Blaisdell 1953). The influence of burning on perennial grasses depends on timing and intensity of the fire and the species of grass involved (Wright and Klemmedson 1964). Generally, herbage production of most perennial grass species is initially reduced, but long-term production is enhanced from the reduced competition from shrubs. Prescribed burning has often been proposed as a tool to restore the balance between shrub and grass species (Pechanec et al. 1954).

There are several species of root-sprouting shrubs present in most big sagebrush communities that dynamically respond to fire and temporarily (10 to 15 years) dominate the overstory

(Young and Evans 1974). Harniss and Murray (1973) provided a summary of 30 years of succession following controlled burning of sagebrush/grasslands that illustrates the ultimate reestablishment of big sagebrush.

An innovative approach to addressing the problem of wildfire frequency in a pristine big sagebrush environment has been expressed by Wright (1977). He considered that the interval between fires had to be greater than the period of dominance of the root-sprouting subdominant shrubs, which is roughly 10 to 15 years. If the interval between wildfires was less than the period of seral shrub dominance, the environment would have been characterized by root-sprouting shrubs rather than big sagebrush.

Stand renewal in big sagebrush communities of the Great Basin has been revolutionized during the last century by the introduction of domestic livestock and by the introduction of alien plant species (Young et al. 1972). The niche for large herbivores that is filled by domestic livestock has been vacant since the close of Pleistocene (Martin 1967). Thus, during the last century, native perennial grasses have been subjected to unprecedented grazing pressure. Piemeisel (1951) was the first to recognize and interpret the impact of alien introduction on succession on big sagebrush/grasslands.

Methods

Three wildfires in seral big sagebrush/Thurber needlegrass in the area 30 to 50 km north of Reno, Nev., were sampled. The dates of the fires and the areas burned were: (a) Red Rock, 1972, 800 ha; (b) Hallelujah Junction, 1973, 16,000 ha; and (c) Seven Lakes, 1974, 4,000 ha. The fires burned during the last week in July or the first 2 weeks in August. Obviously, the large fires burned many different plant communities, but the landscape-characterizing communi-

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ty was big sagebrush/Thurber needlegrass. This was the community to which we restricted our sampling. The stratification for site potential was based on remnant vegetation, topo-edaphic features, and the previous knowledge of the burned areas. Much of the preburn environment had been subjected to investigation before the fires (e.g. Kennedy and Doten 1901; Young and Evans 1974). Soils are Aridisols derived from decomposing granite or quartz diorite. Elevation ranges from 1,500 to 1,800 m, with annual precipitation (primarily snow), ranging from 20 to 25 cm.

Based on earlier investigations (Kennedy and Doten 1901; Young and Evans 1974) and records of the public land management agencies, it is apparent that virtually all of the recently burned area had previously been burned at least once since 1900. Grazing by domestic livestock has been continuous and generally excessive since 1870.

The first phase of sampling consisted of locating 10 permanently marked m^2 quadrats at specifically chosen points in each sampling site of each burn. In the Red Rock burn 100 plots were marked, 250 were established in the Hallelujah Junction burn and 50 in the Seven Lakes burned area. Each plot was located over a burned perennial grass bunch or shrub stump. The m^2 quadrats were divided with a 10×10 -cm grid to facilitate charting the location of multiple grass or shrub stumps and to aid in ocular estimates of ash and unburned litter cover. The marked plots were resampled annually at the end of the spring growing season. The recovery or mortality of the charted perennial species was recorded and herbage cover and density of reestablishing species were recorded.

The second phase of sampling consisted of 10 randomly located 10-m^2 plots at each site sampled. Shrub density, height, and cover were obtained on each plot annually at the end of the growing season. In addition, frequency and cover of herbaceous vegetation were obtained by use of the step-point technique of Evans and Love (1957). This sampling was done at the end of the spring growing season the first year after burning and was repeated annually.

In 1973, the first growing season after the Red Rock burn, we randomly selected 400 to 500 downy brome plants from the burned area and from the adjacent areas of the same potential and seral state that were unburned. We counted the numbers of tillers per plant and numbers of immature caryopses per plant.

Results

Herbaceous vegetation

Comparing the density of perennial herbaceous species immediately after the fire with that recorded the next growing season revealed few differences in density or evidence of mortality

Table 1. Density (number/ m^2) of perennial grasses and forbs immediately after burning in wild-fires and in one through four subsequent growing seasons. Data from 100 permanently marked plots on Red Rock burn.

Plant species	Time after burning				
	1 month	1 year	2 years	3 years	4 years
Perennial grasses					
<i>Elymus cinereus</i>	0.02	0.02	0.02	0.01	0.01
<i>Oryzopsis hymenoides</i>	T ^a	T	T	T	T
<i>Poa sandbergii</i>	0.42	0.57	0.51	0.44	0.46
<i>Stipa comata</i>	0.02	0.03	0.06	0.02	0.04
<i>S. speciosa</i>	T	T	T	T	T
<i>S. thurberiana</i>	0.18	0.14	0.12	0.16	0.16
<i>Sitanion hystrix</i>	0.32	0.30	0.41	0.30	0.30
Total grasses					
	0.96	1.06	1.12	0.93	0.97
Perennial forbs					
<i>Balsamorhiza sagittata</i>	0.10	0.10	0.17	0.20	0.31
<i>Lupinus caudatus</i>	0.09	0.08	0.14	0.16	0.16
<i>Wyethia mollis</i>	0.08	0.07	0.06	0.06	0.06
<i>W. amplexicaulis</i>	0.09	0.06	0.08	0.11	0.10
Total forbs	0.36	0.31	0.45	0.53	0.63
Total perennials	1.32	1.37	1.57	1.46	1.60

^a T represents less than 0.01 plants per m^2 .

ty due to the fire (Table 1). There was a slight increase in density of Sandberg bluegrass (*Poa sandbergii*), which reflects the difficulty in distinguishing individual plants of the species when they are freshly burned.

In previous studies in this environment, we determined that 2.5 perennial grass plants per m^2 are necessary to preempt the environmental potential released by removing the shrub portion of the community (Young and Evans 1974; Evans and Young 1975). Unless this density of perennial grasses was present, the site was subject to invasion by alien annual species and/or shrub seedlings. Note that the season after

burning the density of perennial grasses was slightly more than 1 plant per m^2 and total perennial herbaceous species density was 1.4 plants per m^2 (Table 1). Obviously, the burning of the shrubs and lack of herbaceous perennials provided environmental potential to fuel the increase of opportunistic colonizing species. We have presented density data only for the Red Rock fire, where we have the longest time base; but a similar lack of herbaceous perennials was also evident on the other two burns. The low percentage herbaceous cover (12%) the first growing season following the burning (Fig. 1) also reflected the openness of the post-

Fig. 1. Projected herbage cover of herbaceous species in a seral big sagebrush/Thurber needlegrass community through 4 years after burning in the Red Rock wildfire.

burn communities.

Downy brome was the most frequent herbaceous species the first season after burning on all three burns (Table 2). However, annual forbs and especially native annuals, such as little flower collinsia (*Collinsia parviflora*) or Brewers mimulus (*Mimulus breweri*), rivaled and additively exceeded downy brome in frequency.

The bulk of the reproductive reserve of downy brome was located under the big sagebrush canopies in these communities before burning (Young and Evans 1975). The accumulation of litter and nutrients and the more favorable microenvironment resulted in more plants and greater growth of herbaceous species under shrubs than in the interspaces (Schlatterer and Hironaka 1972). This accumulation of herbaceous and woody fuels in and below shrubs resulted in uneven burning of the sagebrush/grass communities in wildfires.

The bulk of downy brome reproductive reserve of germinable and dormant seed was consumed in the hot fire

resulting from burning of the shrub. Relatively few caryopses survived in the shrub interspaces to provide a source for reestablishing the population the first season following the fire (Young et al. 1976).

The shrub vs interspace environments that contrasted so in the degraded sagebrush/grass communities before burning (Schlatterer and Hironaka 1972) were also present after burning. The first growing season after burning, downy brome was virtually absent from the blacken-ash rings of the old shrub canopies and established only in the shrub interspaces. The native annual forbs colonized the ash accumulations from the shrubs.

Alien forbs, such as Russian thistle (*Salsola iberica*) or tumble mustard (*Sisymbrium altissimum*), which characterized the first stages of abandoned field succession in Piemeisel's (1951) classical sequence for the sagebrush/grasslands in the intermountain west, were absent or relatively unimportant in these communities (Table 2). The sparse but highly competitive stand of

downy brome that reestablished the first season after burning was sufficient to suppress these seral stages (Young and Evans 1973).

In a community of some 30 herbaceous species, population dynamics following burning were rather stagnant for most members except downy brome. The density of downy brome the first season following burning was less than 10 plants/m². By 3 years after burning, the density was greater than 10,000 plants/m² (Fig. 2). This tremendous preemption of environmental potential dampened the expression of dynamics by other species.

Although the density of downy brome plants was very low the first year after burning, the vigor of the individual plants was tremendous. In both numbers of tillers and caryopses produced per plant, the populations of downy brome on burned areas were far more productive than those found on adjacent unburned areas (Figs. 3 and 4). In number of caryopses per plant, the populations did not overlap. The lowest caryopses production per plant

Table 2. Herbaceous species composition based on frequency on three wildfires 1 through 4 years after burning.

Plant species	Years after burning in wildfire								
	1st Season			2nd Season			3rd Season		4th Season
	Red Rock	Hallelujah	7 Lake	Red Rock	Hallelujah	7 Lake	Red Rock	Hallelujah	Red Rock
Perennial grasses and sedges									
<i>Carex douglasii</i>	T ^a	T	0	T	T	0	T	T	T
<i>Elymus cinereus</i>	2	2	2	T	T	T	T	T	T
<i>Oryzopsis hymenoides</i>	T	1	3	T	T	2	T	T	T
<i>Poa sandbergii</i>	7	3	3	2	2	1	3	1	2
<i>Stipa comata</i>	3	1	T	3	1	T	2	1	2
<i>S. occidentalis</i>	0	2	0	0	1	0	0	2	0
<i>S. speciosa</i>	T	1	2	T	T	T	T	T	T
<i>S. thurberiana</i>	3	3	4	1	2	2	2	2	1
<i>Sitanion hystrix</i>	3	2	3	1	1	2	3	4	4
Annual grasses									
<i>Bromus tectorum</i>	23	13	15	74	68	60	57	61	50
<i>Vulpia octobloria</i>	2	T	4	0	0	0	0	0	0
Perennial forbs									
<i>Astragalus filipes</i>	T	0	0	T	0	0	T	0	T
<i>Balsamorhiza sagittata</i>	11	7	12	4	2	10	8	8	9
<i>Crepis acuminata</i>	1	3	T	0	1	T	0	0	0
<i>Lupinus caudatus</i>	10	9	11	3	2	7	6	8	10
<i>Lygodesmia spinosa</i>	0	T	2	1	2	6	5	11	8
<i>Phlox diffusa</i>	5	3	2	1	T	T	2	T	5
<i>Sidalcea glaucescens</i>	T	0	0	T	0	0	T	0	0
<i>Wyethia mollis</i>	T	T	0	T	T	0	T	T	1
<i>W. amplexicaulis</i>	3	2	2	2	1	2	2	T	4
Annual forbs									
<i>Collinsia parviflora</i>	10	9	7	T	0	0	0	0	1
<i>Descurainia pinnata</i>	T	T	6	1	3	2	3	0	T
<i>Eriogonum baileyi</i>	2	5	3	T	2	2	T	2	0
<i>Gilia brecciarum</i>	T	T	T	T	0	0	0	T	0
<i>Mimulus breweri</i>	8	12	14	T	0	0	0	0	0
<i>Mentzelia perfoliata</i>	1	5	1	2	1	0	1	T	0
<i>Montia perfoliata</i>	T	T	0	0	0	0	0	0	0
<i>Nicotiana attenuata</i>	0	11	0	0	1	0	0	0	0
<i>Sisymbrium altissimum</i>	1	1	2	3	2	2	4	T	0
<i>Phacelia mertensia</i>	3	1	0	0	0	0	0	0	0

^a T - indicated less than 1% frequency.

Fig. 2. Density of downy brome plants per m² on seral big sagebrush/Thurber needlegrass communities 1 through 4 years after burning in wildfires.

on the burn was 960, while the maximum by unburned plants was 250. The number of tillers per plant is important because it extends the flowering period and enhances the chances for hybridization among plants. The reproductive response of the reduced population of downy brome that establishes after the wildfires is an expression of phenotypic plasticity. This plasticity is an obvious response to reduced competition, but the phenotypic response paves the way for changes in breeding systems that have genotypic consequences.

Downy brome plants are largely self-pollinated, and in unburned communities hybridization probably rarely occurs. The release in environmental potential brought on by the destruction of the dominant woody component of the community and the partial reduction in downy brome reproduction potential pave the way for hybridization and recombination. This is an application of the genetic system for predominantly self-pollinated species established by Stebbins and Allard (e.g. Allard 1965). Annual species of *Bromus* are the prime, but not only,

Fig. 3. Number of tillers per plant on randomly selected downy brome plants from Red Rock burned area the first growing season after the fire and in an adjacent unburned area.

example of this type of breeding system. We have shown in previous studies that medusahead (*Teucrium asperum*) populations exhibit the type of variability associated with largely self-pollinated species (Young et al. 1968). We carry the concept a logical step farther and suggest that the progeny of the hybrids express population heterosis in the F₁ generation, i.e., the second year after burning (Young and Evans 1976). Note that the population density of downy brome the second year after burning, when we propose the expression of population heterosis, is one-quarter to a third of the population density observed the third year following burning; but the competition from downy brome during the second year largely purges the community of native annuals (Table 2; Fig. 1).

The second year after burning, when the downy brome population increases, the plants invade the haloes of ash from the burned shrub canopies occupied by native annuals the season before. The burned shrubs provide a relatively nutrient-rich environment, especially in nitrogen (Schlatterer and Hironaka 1972), for full expression of the potential of downy brome. The nitrogen resulted from nitrification of decaying accumulations of shrub and herbaceous litter under the shrubs and possible cryptogamic fixation (Snyder and Hullstein 1973; Charley and West 1975). The organic nitrogen in the litter under the shrubs is mostly lost through volatilization when burned, but there is a relatively large accumulation of nitrate-N in the soil under the burned canopies compared to the interspaces between the shrubs. The nitrogen was made available for downy brome by the fire in the sense that the shrub competition was removed, intraspecific competition reduced, and a suitable seedbed prepared.

The only other herbaceous species to respond positively in the post-burn environment were the robust perennial forbs not preferred by grazing herbivores. This group included balsam root (*Balsamorhiza sagittata*), silver lupine (*Lupinus caudatus*), mules ear (*Wyethia mollis*), wyethia (*Wyethia amplexicaulis*), and spiny skelton weed (*Lygodesmia spinosa*). These species increased in frequency (Table 1) and density (Table 2).

Consequences of herbaceous succession

By the third year after burning the

population dynamics of downy brome had stabilized at a new dynamic equilibrium. Cover and density fluctuated with growing conditions (Evans et al. 1970). The environment was closed to seedlings of perennial grasses (Robertson and Pearse 1945) so that the natural succession pattern to a sagebrush/perennial grassland equilibrium was irrevocably altered.

By 2 years after burning, the downy brome populations that hybridized were segregating. Many of the new combinations were probably of no selective value, but those that had selective advantages for micro-niches in the site lapsed into self-pollination and produced stable duplicates of themselves.

A major consequence of the dynamics of downy brome was a loss of annual species diversity. On the Red Rock burn diversity of herbaceous species progressively dropped, 20, 50, and 70% in the three growing seasons following reestablishment (Table 2). Similar reductions were apparent for the shorter time scale on the other two burns. Comparing the data for the downy brome-dominated communities with that in published accounts of the species composition of pristine big sagebrush/Thurber needlegrass communities further illustrates how greatly species diversity was reduced (Young et al. 1977). If our model for the population dynamics is correct, there would be a progressive increase in intraspecific diversity of downy brome over the same time period.

Shrub dynamics

Based on the density of burned shrub stumps immediately after the fires, the dominant shrub in preburn communities was big sagebrush (Table 3). As expected, none of the burned big sagebrush plants sprouted. The two major subdominant shrubs were green rabbit-

Fig. 4. Downy brome caryopses production per plant in the Red Rock burn and in an adjacent unburned area the first season after burning.

Fig. 5. Projected herbage cover and constancy of shrub species on Red Rock burn 4 years after wildfire.

brush (*Chrysothamnus viscidiflorus*) and horsebrush (*Tetradymia canescens*). Both species sprouted vigorously, with horsebrush having the higher

survival rate.

Three occasionally occurring shrub species, desert peach (*Prunus andersonii*), currant (*Ribes velutinum*), and green ephedra (*Ephedra viridis*), were vigorous sprouters after burning with virtually all plants producing new stems that survived (Fig. 5).

The pattern of growth of sprouts after burning was quite variable. Green rabbitbrush characteristically has one sprout per burned plant. The new stem develops from a bud near the soil surface. Horsebrush, the other subdominant shrub, sprouts from roots located well below the soil surface. Each burned horsebrush plant produced several new shoots. A single burned

Table 3. Mean density (number/m²) of shrubs recorded on the area of each fire after burning and percent resprouting the next growing season. Density based on number of stems per unit area. See text for difficulty in comparing density of clonal and new clonal species.

Shrub species	Shrub density/10 m ² and percent resprouting					
	Red Rock		Hallelujah		7 Lakes	
	Density	Sprouting	Density	Sprouting	Density	Sprouting
<i>Artemisia tridentata</i>	2.82	0	3.14	0	2.66	0
<i>Chrysothamnus viscidiflorus</i>	0.91	85	0.41	81	0.62	76
<i>Tetradymia canescens</i>	0.38	96	0.62	93	0.71	98
<i>Prunus andersonii</i>	0.09	100	0.10	100	0.08	100
<i>Ephedra viridis</i>	0.02	98	0.01	100	0.03	100
<i>Ribes velutinum</i>	0.08	100	0.06	100	0	

horsebrush shrub may produce 5 to 7 sprouts, with 1 to 2 dm spacing between sprouts.

Desert peach, ephedra, and currant were distributed in definite clumps. These clumps represent individual or multiple clones that can occupy a quite extensive area. Desert peach plants sprout from lignotubers and an extensive network of underground stems. Ephedra also sprouts from extensive woody crowns. Currant sprouts, after burning, with a host of armed stems. These stems often trap wind erosion products, and soil mounds develop over the area of the clone (Saunders et al. 1973).

The net effect of these various resprouting habits is to make it difficult to obtain a single meaningful parameter to assess shrub succession.

Green rabbitbrush was the only shrub species to establish large numbers of seedlings (Table 4). In a previous study we showed how green rabbitbrush responds dynamically to burning in wildfires by sprouting, tremendous achene production, and subsequent seedling establishment (Young and Evans 1974).

If we had a longer post-burn time-scale, seedling establishment of sagebrush would become increasingly important (Harniss and Murray 1973). The three clonal species had virtually no seedling establishment after the burns.

It is important to note that no shrub seedlings established the first season after burning. This indicates either a lack of shrub seed reserves in the litter and soil or their destruction by burning.

Discussion

The dominance of downy brome after wildfires in sagebrush grasslands resembles the phoenix of an alien life form rising from the ashes to haunt the post-burn environment (Young et al. 1976). However melodramatic the

analogy, the implications of this study of post-burn population dynamics are a clear documentation of environmental degradation.

The sagebrush/grassland ecosystems that have existed in the Great Basin only since the Pleistocene (Axelrod 1950) have, within the span of a single century, been irreversibly altered by the husbandry of domestic livestock and unintentional introduction of alien plant species. The natural equilibrium of a vegetation composed of sagebrush/stipa communities will never again be attained, but only can be approached through the use of exotic species. It is easy to rationalize the magnitude of this degradation by enumerating the many areas of sagebrush/grasslands where downy brome is absent and native perennials still dominate. These areas are a valuable resource worthy of protection to maintain their economic and scientific values. Close examination often reveals high seral sagebrush/grassland communities remaining on areas at higher elevation under more mesic conditions, and/or long distances from stock water. If you doubt the colonizing ability of alien weeds, remember that at the turn of the century there was no downy brome in northern Nevada (Kennedy and Doten 1901). Unfortunately, modern technology has accelerated environmental degradation in sagebrush/grasslands rather than impeded it. Probably, conversion of sagebrush lands to annual grasslands has been greater in one century around urban areas and along railroads in the Great Basin than during the entire first millenium of livestock grazing in *Artemisia* steppes of Asia.

Downy brome has the inherent competitive ability to close seral communities to seedlings of perennial grasses. We have provided in this study additional evidence of how the breeding system of this species is closely tuned to the demands of diverse and changing environments. Downy brome

literally fuels its own dynamics by providing the accumulation of fine herbage that ignites and carries wildfire to the widely spaced sagebrush plants.

During the 1930's, R. L. Piemeisel and G.P. Pickford clearly enumerated the preemption of seral habitats in the sagebrush/grasslands by alien annuals. They clearly visualized this as a cyclic phenomenon accelerating in a concentric spiral, with conversion to an annual grassland as the ultimate result. Pickford recognized that once the alien spiral was initiated, complete removal of domestic livestock would not stop the ultimate environmental conversion. There is strong evidence that removal of livestock would actually accelerate conversion to annual dominance because of fuel accumulations.

Downy brome dominance is the symbol of environmental degradation if the pristine vegetation is used as the benchmark of judging range condition. However, the current livestock industry in large areas of the Great Basin is partially dependent on downy brome as a forage base.

Downy brome is not the ultimate in potential environmental degradation. Small portions of the sagebrush/grassland of the Great Basin have been degraded past downy brome dominance to scotch thistle (*Onopordum acanthium*) and/or medusahead (*Taeniatherum asperum*) dominance. These communities represent a very limited grazing resource compared to downy brome or to potential vegetation.

By dietary preference and life-style, the American public demands quality animal protein. Among vertebrates, only the ruminants have evolved digestive systems capable of converting high ligna-cellulose herbage to animal protein. As feed grains increase in value in the international marketplace, rangelands become more important in red meat production. Life-styles can be forced to change and a finite amount of plant protein be substituted in diets, but the requirements for quality protein so outstrip supply that use of rangeland resources remains essential. The population dynamics presented in this paper document for one community the fact that the forage resource of the sagebrush/grasslands are being degraded.

We have described a biological process in terms of a sequence of ecological events. Answering to this degradation is not simply the responsibility of land management agencies or

Table 4. Shrub seedling establishment per 10 m² on Red Rock burn 1 through 4 years after burning.

Shrub species	Seedling establishment/10 m ² years after burning			
	1	2	3	4
<i>Artemisia tridentata</i>	0	0.01	T ^a	0.02
<i>Chrysothamnus viscidiflorus</i>	0	0.89	1.02	0.61
<i>Tetradymia canescens</i>	0	T	0.03	0.18
<i>Prunus andersonii</i>	0	0	0	0
<i>Ephedra viridis</i>	0	0	0	0
<i>Ribes velutinum</i>	0	0	T	0.01

^a T indicates less than 0.01 seedlings per 10 m².

ranchers. The degradation of sagebrush/grass ranges is a product of our culture.

The livestock husbandryman of the 19th century initiated exploitation of the sagebrush/grasslands without precedence and without experience in a similar environment to guide their actions. Throughout the entire history of herbivore domestication, alien plant species and, we suspect, associated opportunistic vertebrate and invertebrate faunas have evolved a counter culture to man's husbandry of animals. We now have a century of experience with domestic animals in the Great Basin, a half century of ecologic research, and evidence from antiquity of the impact of prolonged haphazard animal husbandry on the *Artemisia* steppe of southwestern Asia (Flannery 1969). Despite this accumulation of ecological knowledge and practical experience, there is currently no application of appropriate technology for the restoration of plant communities in this environment. As a consequence, we propose that the breeding system and population dynamics of downy brome should be used as a model for 21st century ecology, improvement, and management of the sagebrush/grasslands and, with modification, much of the semiarid portions of the world.

Dynamics is the essence of the data of this study. The dynamics of degraded sagebrush/grasslands cannot be stopped by the desire, no matter how well motivated, to preserve the current plant communities and their environment. The process has been initiated and equilibrium will return only with degradation of the ecosystem under current land management policies. Application of appropriate technology to stem the tide of degradation does not only mean conversion of degraded sagebrush/downy brome communities to perennial grasslands for livestock production. It also means reestablishment of stable perennial shrub, forb, and grass-dominated communities with associated biotic and physical factors, including fire, to be in equilibrium with the potential of the environment. The environmental impact of man's activi-

ties on this ecosystem has been and will be stated many times with increasing precision and clarity. What remains to be done is affirmative action to improve these plant communities for environmental stability and increased productivity.

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