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Decline of western sage grouse (*Centrocercus urophasianus phaios*) in Oregon may be related to the reduced availability of foods in upland sagebrush (*Artemisia*)-grasslands used for brood-rearing. The goal of this study was to determine primary foods of chicks and the short-term response of brood-rearing habitat to prescribed burning at Hart Mountain, Oregon.

Analysis revealed that food use by 44 chicks and availability at collection locations differed ($P > 0.001$) among forb and insect taxa. Eleven forb and insect genera were used selectively (primary foods) and collectively composed 58% of the diet by aggregate mass. Primary foods included Cichorieae (*Crepis* sp., *Agoseris* spp., *Taraxacum* sp.), milkvetches (*Astragalus* spp.), microsteris (*Microsteris* sp.), desert-parsley (*Lomatium* spp.) and ground-dwelling beetles (Scarabaeidae, Tenebrionidae). Compared with 1-5 week-old chicks, 6-10 week-old chicks consumed less ($P < 0.05$) annual forbs (36 and 14%) and ground-dwelling insects (32 and 16%) but more perennial forbs (30 and 55%) and sagebrush (2 and 16%) by aggregate mass.

Response of brood-rearing habitat to prescribed burning was evaluated in sagebrush-bitterbrush (*Purshia tridentata*) communities with a randomized block design established in stands where shrub cover exceeded 35%. Within blocks, habitat response was evaluated for 2 growing seasons on 4 plots used as controls, 3 plots burned in November 1987, and 4 plots burned in March 1988. Fall burning increased ($P < 0.05$) frequency of Cichorieae. Other primary foods, including microsteris, desert-parsley, and ground-dwelling beetles, were not influenced by burning. Additionally, spring and fall burning reduced shrub cover and increased total forb cover and diversity, but grasses and insect orders were not substantially influenced.

Although prescribed burning increased habitat heterogeneity, its utility may be limited as a food enhancement practice. Primary forbs and insects responded inconsistently and sagebrush, which serves as both food and cover, responded negatively. Evaluation of brood-rearing habitat should be based on several criteria including an understanding of the interaction between land-use practices and availability of primary foods of chicks.

Response of Brood-rearing Habitat of Sage Grouse to Prescribed Burning in Oregon

by

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Typed by William H. Pyle

For my loving parents MaryJane and Donald

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INTRODUCTION

Survival and productivity of sage grouse (Centrocercus urophasianus) are related to the availability of food in shrub-steppe habitats of western North America (Peterson 1970, Wallestad et al. 1975, Johnson and Boyce 1990). Sage grouse consume sagebrush (Artemisia tridentata) from fall to spring (Wallestad et al. 1975), but during summer, the availability of insects and forbs influences patterns of bird distribution (Klebenow 1969, Martin 1970, Wallestad 1971, Boyce 1982, Drut 1993), intensity and duration of habitat use (Oakleaf 1971, Evans 1986), diet composition (Klebenow and Gray 1968, Peterson 1970), and survival rates (Johnson and Boyce 1990).

Sage grouse were common in sagebrush-grassland habitats of eastern Oregon in the 1800s (Henshaw 1880, Gabrielson and Jewett 1940:217). Sage grouse distribution contracted >50% since 1900 and abundance declined >60% since 1941 (Crawford and Lutz 1985). Reduced abundance was associated primarily with impaired success of nests and diminished survival of chicks (Crawford and Lutz 1985, Gregg 1991). Concerns about the status of these birds prompted the 1985 listing of western sage grouse, C. u. phaios (Aldrich 1946), as a candidate for federal protection (Federal Register 50:37963).

Sage grouse nest in upland shrub communities dominated by Wyoming big sagebrush (A. t. wyomingensis), low sagebrush (A. arbuscula), sagebrush and bitterbrush (Purshia tridentata), and mountain big sagebrush (A. t. vaseyana) (Klebenow 1969, Connelly et al. 1991, Gregg 1991). After nesting, hens with broods establish home ranges in upland communities for 5-12 weeks (Klebenow 1969, Wallestad 1971, Drut 1992). Shrub cover at sites used by broods averaged 6-15% in Idaho and Montana, but seldom exceeded 30% (Klebenow 1969, Peterson 1970). Forbs and insects were the main forage classes used by chicks (Klebenow and Gray 1968, Peterson 1970). Primary foods of chicks included geographically widespread species such as common dandelion (Taraxacum officinale) and locally available species such as harkness gilia (Linanthus harknessii) in Idaho (Klebenow and Gray 1968), curlcup gumweed (Grindelia squarrosa) in Montana (Peterson 1970), and western aster (Aster occidentalis) in Nevada (Savage 1969). In Oregon, Batterson and Morse (1949) and Nelson (1954) listed ants (Formicidae), wild lettuce (Lactuca), phlox (Phlox), and desert-parsley (Lomatium) as foods, however, amounts used by birds were not reported.

Availability of primary foods influences foraging behavior of many galliformes (Gullion 1966). During summer, sage grouse hens with broods compensated for changes in food availability by selection for different cover types (Martin 1970, Peterson 1970, Drut 1992). Among cover types, home ranges of hens with broods were largest where primary forbs and insects were least available to chicks (Drut 1992). Consequently, availability of primary foods may influence chick survival by affecting foraging strategy, nutritional status, and frequency of exposure to predators (Bergerud and Gratson 1988:614, Johnson and Boyce 1990, Drut 1992).

After Euro-American settlement, many upland communities within sage grouse range diminished in productivity and diversity: shrubs increased, and native forbs and grasses declined (Blaisdell et al. 1982, Winward 1991). Reduction of forbs and grasses was attributed to selective grazing by domestic livestock (Laycock 1967, Rickard 1985), competition between shrubs and forbs (Tisdale et al. 1969, Winward 1991), the tendency for succession to proceed from forb to shrub dominated stands (Harniss and Murray 1973, Humphrey 1984), introduction of Eurasian grasses such as cheatgrass (Bromus tectorum) (Young et al. 1972), and suppression of fire (Shinn 1978, Winward 1985, Kauffman 1990). Where prevalent, shrubs dominated forbs and grasses (Blaisdell 1953, Mueggler and Blaisdell 1958, Sneva et al. 1984, Laycock 1991).

Historically, fire was the primary process that influenced secondary succession in the Intermountain West (Wright et al. 1979, Winward 1985, Kauffman 1990). Stand-replacement fires periodically burned brood-rearing habitat, including mountain big sagebrush and associated communities (Burkhardt and Tisdale 1969, Klebenow 1969, Klebenow 1970, Wright et al. 1979, Kauffman 1990, Klott and Lindzey 1990, Drut 1992). Burning may have negative or positive effects on sage grouse depending on what habitat is burned, the timing of burning, and how food and cover are affected (Klebenow 1972, Autenrieth et al. 1981). However, no study examined whether prescribed burning can be used to enhance food supplies for chicks (Klebenow 1972, Autenrieth et al. 1982). The objective of this study was to determine the short-term effects of fall and spring prescribed burning on frequency and cover of primary plant food and abundance of primary arthropod food. Additionally, I evaluated food use and selection to determine primary foods of chicks.

STUDY AREA

Food use and selection by chicks and prescribed fire in brood-rearing habitat were evaluated at Hart Mountain National Antelope Refuge (NAR), Lake County, Oregon during 1988 and 1989. Hart Mountain, a fault-block range, is located in the Lake Floristic Province of the northern Great Basin (Cronquist et al. 1972). Prominent cover types distributed in non-riparian locations included Wyoming big sagebrush, low sagebrush, sagebrush-bitterbrush, western juniper (Juniperus occidentalis), mountain big sagebrush, and aspen (Populus tremulodies). Mean precipitation measured between September and July at refuge headquarters (1680-m elevation) was 27 cm between 1941-1987 and 22 cm in 1988-89. Mean air temperature between March and July was 13 C between 1939-1987 and 10 C between 1988-89. Density of sage grouse was estimated at 2.5 birds/km^2 during the 1980s and productivity averaged 1.7 chicks/hen in 1988-89 (M. Smith, U. S. Fish Wildl. Serv., pers. commun.).

METHODS

Food Use and Diet Selection

Sage grouse broods were located between 1800-2100 PDT of June and July of 1988-89 along a series of roads and trails that intersected upland sagebrush and grassland communities. I collected 1 chick/brood with a shotgun after foraging was observed for a minimum duration of 1 minute. Each foraging location was marked for subsequent vegetation analysis. Age of chicks was determined by primary replacement (Pyrah 1963). Crops were examined, contents separated, and food items identified to the lowest taxon possible. Food mass was assessed to the nearest 1 mg after items were oven-dried to constant weight.

Vegetation and arthropods were sampled at collection sites within 7 days after a chick was collected. A 0.04-ha circular plot was established at each foraging location; 4 11.3-m transects were established and oriented in cardinal directions. Frequency of grasses and live forbs was sampled in 30 rectangular, nested quadrats (250, 500, 1000-cm^2) arranged along transects (see Smith et al. 1986). Plant frequency data were compiled with a summation procedure (Smith et al. 1987). Shrub cover was sampled with the line-intercept method (Canfield 1941). Arthropod frequency was sampled in 12 pitfall traps (Morill 1975) established for 3 days along transect lines.

Food usage was computed as the mass of a food/total food mass of a crop (aggregate mean percentage) (Swanson et al. 1974). For comparison with other studies, usage also was summarized as mass of a food/total food mass of the overall diet (aggregate percentage). Food availability was calculated as the relative frequency of forbs, grasses, and arthropods and cover of shrubs averaged among collection sites. Food selection was determined for each forage class (e.g., forbs) with PREFER (Johnson 1980). Number of diet components analyzed with PREFER was determined *a priori* based on the amount and consistency of use of individual components. Consequently, analysis included foods whose (1) use exceeded >1% aggregate weight and >10% frequency in the diet and (2) use <10% frequency in the diet, "other" foods. Subsequently, percentages of foods used and available within a forage class were ranked, vectors of use and availability were derived from averaged ranks, and vectors were compared with the Hotelling T^2-statistic (Anderson 1958) to determine if selection differed ($P > 0.05$) among foods. To determine which foods were used selectively, pairwise differences were tested with the Waller-Duncan K-ratio t-test ($K = 100$) (Waller and Duncan 1969).

Previous studies indicated that habitat use and diet of chicks changed at 4-6 weeks of age (Klebenow and Gray 1968, Peterson 1970, Wallestad 1971, Drut 1993). Therefore, I compared use of forage classes by 2 age groups of chicks and availability of forage classes to age groups with t-tests. Significance was evaluated at $P < 0.05$.

Prescribed Burning

Mountain big sagebrush-bitterbrush was selected for evaluation of the effects of prescribed fire based on use as brood-rearing habitat (Klebenow 1969, Klott and Lindzey 1990). A 100-km^2 study area was delineated from aerial photographs based on the distribution of mountain big sagebrush-bitterbrush. Within the study area, sagebrush-bitterbrush was distributed on ridges, slopes <30°, and alluvial fans where elevations ranged from 1675 to 1980 m, mean annual precipitation ranged from 30 to 41 cm, mean annual air temperature ranged from 5 to 7 C, and the frost-free period ranged from 50 to 90 days (J. Kienzle, U. S. Soil Cons. Serv., pers. commun.). Soil associated with mountain big sagebrush-bitterbrush was classified as a loamy-skeletal, mixed, frigid Cumilic Argixeroll derived from basaltic and tuffaceous alluvium and colluvium (J. Kienzle, U. S. Soil Cons. Serv., pers. commun.).

A randomized block design was used for the experiment. Preliminary sampling conducted in summer 1987 revealed that sites selected for study supported high shrub cover (36-53%) and low forb cover (2-10%). These sites were considered appropriate for treatment because this amount of shrub cover presumably limited forb availability and therefore reduced site use by sage grouse broods (Klebenow 1969, Klebenow 1972, Autenrieth and Mangan 1985, Drut 1992). Consequently, 4 blocks were selected from available stands; 3 treatment plots, each 25 x 40-m, were located within each block and randomly assigned to control, fall burn, or spring burn.

Fall and spring fires, ignited with drip torches, were designed to correspond to the usual period of plant dormancy which occurred between October and April. Above-ground tissue of plants appeared dormant when fall burns were conducted in November 1987. However, leaves of bitterbrush had emerged and growth had initiated for some annual forbs (e.g., microsteris) when spring burns were conducted in March 1988.

Cattle were excluded from plots with electric fences during the post-treatment period.

Fuels, weather, fire characteristics, and shrub consumption were sampled for association with post-treatment vegetal response. Before burning, grasses and forbs were clipped in 20 0.4-m quadrats, dried to constant weight, and weighed to estimate understory fuel biomass. Ten samples of soil, residual grass, and live shrub foliage were collected, weighed, dried to constant weight, and reweighed to estimate moisture content. Wind speed, air temperature, and relative humidity at ignition were recorded to the nearest hour by an automated RAWS weather station located within 11 km of treatment plots at 1683-m elevation. During burning, heights and movement of fire were noted, flame lengths and rate of fire spread estimated, and fire intensity and heat/area calculated (see Rothermal and Deeming 1980). Heat input to soils was measured with fusion pyronometers marked at temperatures of 93 and 260 C and inserted at a soil depth of 0-7 cm (Fenner and Bentley 1960). After burning, residual size of dead sagebrush and bitterbrush stems was measured for 20 dead plants/species/treatment plot to index fire severity.

Vegetation response was sampled during June of 1988 and 1989. Cover of forbs and grasses was sampled with a 10-point frame set at a 45° angle (Sharrow and Tober 1979). Sample size was computed with the "n-test" (Bonham 1989:78). Sample size was based on total forb cover and established at 48 frames/treatment plot. Shannon's diversity index (H') was computed from the natural log of proportional forb and grass cover (Magurran 1988:34). Frequency of forbs and grasses was sampled in nested quadrats, each 250, 500, 1000-cm^2, at 48 locations/treatment plot

(Smith et al. 1986). Point-intercept cover of shrubs was sampled with a 36 point-frame at 20 random locations/treatment plot in 1989 (Floyd 1982). Relative abundance of insects was sampled in 15 randomly located pitfall traps/treatment plot opened for 10 days in mid-June of 1988 and 1989 (Morrill 1975). Shannon's diversity index (H') was calculated from the natural log of proportional abundance for beetles (Coleoptera) and other arthropods (Magurran 1988:34).

A hierarchal approach was adopted for analysis of vegetation and insect responses to fall burning, spring burning, and no burning. Response was determined at the level of individual primary foods of chicks (e.g., genus) and forage class (e.g., total perennial forbs, insect order). Data were analyzed with 2-way analysis of variance (ANOVA) for a randomized block design with repeated measures (Sokal and Rohlf 1981:348). Although comparison of treatments was limited to the post-treatment period, bias was reduced by replication of treatments among areas and replication of measurements between years on permanent subplots. ANOVA was applied in a regression context with The General Linear Model (GLM) appropriate for unbalanced data (Statistical Analysis Institute 1985). An unbalanced design was chosen because data for 1 fall treatment were inconsistent with other fall treatments; high humidity and low wind speed prevented vegetation on 1 plot from burning.

For each response variable, ANOVA entailed testing all higher-order effects (year, block, treatment) and 2-factor interactions, elimination of non-significant effects and interactions, and selection of the best-fit model which in most cases involved comparison among treatments within year. Consequently, treatment means for response variables were partitioned, analyzed, and displayed by year for consistency. If a significant ($P < 0.05$) treatment effect was detected, treatment means were compared and tested with the Least Significant Differences (LSD) procedure (Sokal and Rohlf 1981:244). Examination of standardized residuals revealed that the assumption of constant residual variance was met for dependent variables; analysis, therefore, employed untransformed means. I used Hitchcock and Cronquist (1973) for standard and vernacular names of plants and Borror et al. (1981) for names of arthropods.

RESULTS

Food Use and Diet Selection

A total of 44 chicks, 1 to 10 weeks of age, was collected in June and July of 1988 and 1989. Collections occurred within a 1070 km^2 area, which ranged between 1610 and 2297-m elevation. Diet was composed of 66% forbs, 19% insects, 8% shrubs, and <1% grasses by mass (Table 1). Usage was dominated by Cichorieae (Agoseris spp., Crepis acuminata, Taraxacum officinale, Tragopogon dubius), milkvetches (Astragalus spp.), microsteris (Microsteris gracilis), sagebrushes (Artemisia spp.), June beetle (Diplotaxis tenebrosa), and darkling beetle (Coniontis proba).

Analysis of food use with food availability disclosed that selection differed among forbs ($F = 5.6$, df = 12 and 32, $P < 0.001$) and insects ($F = 26.6$, df = 3 and 41, $P < 0.001$) but not shrubs. Of the 109 taxa used by chicks, 9 forb and 2 insect taxa were used selectively (primary foods). Microsteris, desert-parsley, and most milkvetches and milky-juiced species of Cichorieae were used selectively by chicks. Among arthropods, June beetles and darkling beetles were used selectively compared with other taxa. Collectively, the 11 primary forb and insect foods composed 58% of the diet by mass.

Forage classes used by chicks and available at collection sites differed between age groups (Table 2). Chicks of 1-5 weeks of age consumed significantly greater amounts of annual forbs and ground-dwelling insects than older chicks. As chicks matured, annual forb use diminished, insect intake declined, and perennial forb and shrub use

Table 1. Aggregate mass (%) of foods consumed by sage grouse chicks, frequency (%) of foods at collection sites, and dietary selection by sage grouse chicks, Hart Mountain, Oregon, 1988-89.

Forage class and taxon	Aggregate mass (%) x(SE)	Frequency (%) x(SE)	Selection rank[a]
Forbs			
Tapertip hawksbeard (*Crepis acuminata*)	5.3(1.8)	0.7(0.3)	-1.59 A
Freckled milkvetch (*Astragalus lentiginosus*)	6.7(2.3)	0.7(0.4)	-1.53 A
Microsteris (*Microsteris gracilis*)	11.9(3.9)	3.9(1.8)	-0.92 AB
Basalt milkvetch (*Astragalus filipes*)	2.9(0.4)	0.7(0.4)	-0.82 AB
Common dandelion (*Taraxacum officinale*)	4.3(2.2)	0.4(0.2)	-0.49 AB
Pursh's milkvetch (*Astragalus purshii*)	2.9(2.2)	0.4(0.3)	-0.43 BC
Annual agoseris (*Agoseris heterophylla*)	2.7(1.3)	0.9(0.7)	-0.40 BC
Mountain dandelion (*A. glauca*)	3.6(1.5)	1.2(0.4)	-0.26 BC
Nevada desert-parsley (*Lomatium nevadense*)	3.4(1.8)	0.6(0.3)	-0.20 BC
Yellow salsify (*Tragopogon dubius*)	4.0(0.9)	0.9(0.4)	0.12 C
Arcane milkvetch (*Astragalus obscurus*)	3.9(1.9)	3.0(1.3)	0.26 C
Long-leaf fleabane (*Erigeron corymbosus*)	2.2(1.0)	1.2(0.4)	0.36 C
Groundsmoke (*Gayophytum* spp.)	1.2(0.9)	4.4(1.2)	1.41 D
Other forbs	11.2(2.2)	45.8(3.9)	3.06 D
Total forbs	66.0(4.0)	53.5(3.7)	
Graminoids			
Grasses (Poaceae)	0.1(0.1)	61.4(1.5)	
Rushes (Juncaceae)		1.3(0.7)	
Sedges (Cyperaceae)		7.2(1.8)	
Shrubs			
Mountain big sagebrush[b] (*Artemisia tridentata*)	2.1(0.9)	7.8(1.8)	-0.14 E
Low sagebrush (*A. arbuscula*)	5.2(1.9)	7.4(1.2)	0.07 E
Other shrubs	1.3(0.9)	2.7(0.9)	0.07 E
Total shrubs	8.0(2.2)	18.2(1.9)	
Arthropods[c]			
June beetle (*Diplotaxis tenebrosa*)	8.3(4.2)	4.2(1.9)	-1.09 F
Darkling beetle (*Coniontis proba*)	5.5(1.6)	19.1(3.2)	-0.68 G
Thatch ant (*Formica fusca*)	2.9(1.4)	96.4(1.4)	0.76 H
Other arthropods	2.8(1.3)	89.4(2.1)	1.01 H
Total arthropods	19.2(3.9)	99.4(0.4)	

[a]Taxonomic categories with the same letter within column and forage class were not different ($P > 0.05$).
[b]*A. t. vaseyana*.
[c]Ground-dwelling arthropods only.

Table 2. Characteristics of the diet and collection sites of sage grouse chicks 1-5 weeks of age (n=25) and 6-10 weeks of age (n=19), Hart Mountain, Oregon, 1988-89.

Category (%)	1-5 weeks $\bar{x}$(SE)	6-10 weeks $\bar{x}$(SE)	P[a]
Diet			
Annual forb mass	36(7)	14(5)	0.024
Arthropod mass	32(6)	16(5)	0.055
Perennial forb mass	30(6)	55(7)	0.007
Shrub mass	2(1)	16(4)	0.007
Collection sites			
Annual forb frequency	32(7)	14(17)	0.045
Arthropod frequency	97(3)	98(0)	0.234
Perennial forb frequency	35(5)	39(7)	0.522
Shrub cover	19(2)	18(4)	0.538

[a]Probability that means within row were different $P < 0.05$ (*t*-test).

increased. Annual forbs were more frequent at sites used by 1-5 week-old chicks compared with sites used by 6-10 week-old chicks. Conversely, availability of perennial forbs was not different between age groups.

Prescribed Burning

Analysis of burn treatments indicated that spring fires were more severe than fall fires (Table 3). Significantly drier grass and lower humidity apparently increased the duration that above-ground matter burned in spring compared with fall. Consequently, spring fires heated soils to significantly greater depths (7 compared with 1 cm at 260 C) and consumed significantly larger stems of sagebrush (3 compared with 1 cm diameter) than fall fires.

Cichorieae, desert-parsley (*Lomatium* spp.), microsteris, June beetles (Scarabaeidae), and darkling beetles (Tenebrionidae) were classified as primary foods of chicks, were found consistently on treatment plots, and, consequently, were tested for response to burning (Table 4). Frequency of Cichorieae was not different among treatments in 1988, but was greater on fall-burned plots than other treatments in 1989 ($F = 6.8$, $df = 2$, $P = 0.02$). Frequency of microsteris was least on spring-burned plots in 1988, but was not different in 1989. Desert-parsley, June beetles, and darkling beetles seemingly were not affected by burning. Milkvetch (*Astragalus* sp.) was found in only 2 blocks and therefore was not tested.

Prescribed burning affected forbs and shrubs more than grasses or arthropods (Table 5). Cover of annual forbs was least on spring-burned

Table 3. Physical characteristics of treatment plots before, during, and after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89.

Sample period and characteristic	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	P[a]
Before burning			
Fine fuel load (kg/ha)	325.3(38)	326.8(53)	0.124
Wind speed (kph)	12.3(0.5)	8.0(0.7)	0.003
Air temperature (C)	14.5(2.8)	17.4(1.7)	0.671
Relative humidity (%)	48.0(2.0)	16.8(1.0)	0.000
Soil surface moisture (%)	15.2(1.1)	23.0(2.4)	0.018
Dry grass moisture (%)	18.2(2.4)	6.5(0.9)	0.005
Live foliage moisture (%)	40.8(0.4)	72.8(1.5)	0.000
During burning			
Fire intensity (KW/m)	2420.3(1098)	652.3(223)	0.025[b]
Heat/unit area (KJ/m^2)	256.3(79)	96.8(13)	0.063[b]
Soil heat/depth (mm)			
93 C	6.5(1.1)	15.5(1.0)	0.002
260 C	0.9(0.4)	6.8(0.9)	0.003
After burning			
Residual stem diameter (cm)			
Sagebrush	1.1(0.2)	2.7(0.5)	0.039
Bitterbrush	0.3(0.1)	0.4(0.1)	0.479

[a]Probability that means within row were different $P < 0.05$ (2-way ANOVA).
[b]Statistic based on analysis of log-transformed means.

Table 4. Cover (%), frequency (%), and abundance (no/trap) of primary foods of sage grouse chicks after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row were not different P > 0.05 (LSD test).

Characteristic, taxon, and year	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Forb cover (%)			
Dandelion tribe (Cichorieae)[a]			
1988	0.5(0.2)	2.6(0.7)	1.9(0.7)
1989	1.2(0.2)	3.6(0.3)	2.9(0.9)
Desert-parsely (*Lomatium*)			
1988	0.9(0.4)	0.7(0.4)	0.5(0.5)
1989	0.9(0.3)	1.9(1.0)	0.8(0.6)
Microsteris (*Microsteris*)			
1988	0.3(0.3)	0.1(0.1)	0.0(0.0)
1989	0.9(0.3)	0.3(0.3)	0.6(0.4)
Forb frequency (%)			
Dandelion tribe (Cichorieae)			
1988	47(10)	72(3)	40(11)
1989	50(7)D	78(1)E	67(5)DE
Desert-parsley (*Lomatium*)			
1988	34(15)	38(15)	34(16)
1989	46(12)	64(10)	44(15)
Microsteris (*Microsteris*)			
1988	42(7)A	22(6)B	0(0)C
1989	80(6)	65(9)	48(12)
Insect abundance (no/trap)			
Darkling beetles (Tenebrionidae)[a]			
1988	3.0(0.4)	2.0(0.3)	2.1(0.6)
1989	2.2(0.5)	1.7(0.5)	2.2(0.7)
June beetles (Scarabaeidae)			
1988	0.3(0.2)	0.3(0.3)	0.6(0.3)
1989	0.3(0.2)	0.2(0.2)	0.3(0.2)

[a]Treatment effect and block x treatment interaction were significant P < 0.05 (2-way ANOVA).

Table 5. Cover (%) and diversity (H') of plants by vegetal class after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row were not different, $P > 0.05$ (LSD test).

Characteristic, taxon, and year	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Plant cover (%)			
Forbs			
Annuals			
1988	2(0.3)A	1(1)AB	0.1(0.1)B
1989	3(1)D	3(1)D	5(1)E
Perennials			
1988	5(1)	7(3)	6(1)
1989	5(1)D	10(3)E	10(3)E
Total forbs			
1988	6(2)	8(3)	6(1)
1989	7(1)D	13(3)E	15(3)E
Grasses			
Annuals			
1988	8(3)	4(1)	2(1)
1989	4(1)	7(1)	3(1)
Perennials			
1988	21(4)	14(4)	12(2)
1989	24(4)	20(1)	21(1)
Total grasses			
1988	28(3)A	18(4)B	13(2)B
1989	27(4)	26(1)	24(1)
Shrubs[a]			
1988	--	--	--
1989	35(4)D	10(4)E	5(3)E
Plant diversity (H')			
Total forbs			
1988	0.57(0.11)	0.86(0.18)	0.88(0.11)
1989	0.64(0.06)D	0.95(0.21)E	1.05(0.12)E
Total grasses			
1988	1.26(0.07)	1.26(0.12)	1.13(0.08)
1989	1.20(0.08)	1.25(0.08)	1.11(0.06)

[a]Missing data for 1988 control plots.

plots in 1988, however, these plots had the greatest cover in 1989 (F = 58.8, df = 2, P = 0.0003). Perennial forb and total forb cover were not influenced by fall and spring burning in 1988. In 1989, spring and fall-burned plots had greater perennial forb cover (F = 9.9, df = 2, P = 0.02), total forb cover (F = 16.7 df = 2, P = 0.006), and total forb diversity (F = 13.9, df = 2, P = 0.009) than controls.

Grass cover was least on spring-burned plots in 1988. Plants apparently recovered because no difference was found in cover and diversity of grasses in 1989. Shrub cover was less on burned plots than controls in 1989, despite apparent resprouting by bitterbrush, gray horsebrush (Tetradymia canescens), green rabbitbrush (Chrysothamnus viscidiflorus), and mountain snowberry (Symphoricarpos oreophilus) on burned plots.

The bulk of arthropods trapped on treatment areas comprised 5 orders (Table 6). Burning influenced 2 of 5 orders. Abundance and variance of Hymenopterons was greater on burned plots than controls in 1988 and 1989. Fewer spiders (Araneida) were trapped on burned plots compared with controls in 1989 (F = 19.9, df = 2, P = 0.004). Arthropod diversity was not different after fall or spring burning.

Table 6. Abundance (no/trap) and diversity (H') of arthropods by order after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row were not different P > 0.05 (LSD test).

Characteristic, taxon, and year	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Arthropod abundance (no/trap)			
Ants and wasps (Hymenoptera)[a]			
1988	25(6)	67(53)	65(14)
1989	15(4)	59(41)	43(25)
Beetles (Coleoptera)			
1988	7(1)	6(0.2)	6(1)
1989	5(1)	4(1)	5(1)
Grasshoppers (Orthoptera)			
1988	3(1)	4(1)	4(1)
1989	1(0.2)	2(0.5)	2(0.4)
Jumping bristletails (Thysanura)			
1988	14(5)	6(3)	4(3)
1989	20(14)	14(3)	9(3)
Spiders (Araneida)			
1988	12(1)	8(2)	8(2)
1989	7(1)D	4(0.3)E	4(1)E
Arthropod diversity (H')			
Beetles (Coleoptera)			
1988	0.32(0.07)	0.33(0.10)	0.45(0.05)
1989	0.38(0.08)	0.29(0.08)	0.38(0.04)
Other arthropods			
1988	1.74(0.14)	1.40(0.34)	1.38(0.17)
1989	1.41(0.18)	1.38(0.36)	1.48(0.27)

[a]Treatment effect and block x treatment interaction were significant P < 0.05 (2-way ANOVA).

DISCUSSION

Food Use and Diet Selection

Sage grouse chicks used a diversity of foods in upland habitats at Hart Mountain. Foraging focused, however, on relatively few taxa of forbs and ground-dwelling beetles. Cichorieae and milkvetches collectively composed 45% of the diet by mass at Hart Mountain. Cichorieae and milkvetches composed 52-65% of the diet of chicks and 30-51% of the diet of adults in summer (June-September) in Idaho and Montana (Klebenow and Gray 1968, Martin 1970, Peterson 1970 Wallestad et al. 1975). Microsteris, a diminutive annual forb, composed 16% of the diet of young chicks at Hart Mountain. Annual forbs composed up to 45% of diets of chicks <6 weeks-old in other areas (Klebenow and Gray 1968, Peterson 1970). Ground-dwelling beetles (e.g., Carabidae, Scarabaeidae, Tenebrionidae) composed 12% of the diet of chicks at Hart Mountain and 1-3% of the diet of chicks in Montana and Idaho (Peterson 1970, Klebenow and Gray 1968). At Hart Mountain, use of sagebrush increased as chicks matured. Other studies consistently identified sagebrush as an important food, despite its limited intake (Klebenow and Gray 1968, Peterson 1970).

Differential use of forage classes seemingly corresponded to change in the nutritional requirements of chicks and seasonal change in the availability of primary foods (Klebenow 1969, Johnson and Boyce 1990, Drut 1992). Although chicks require insects for optimum growth and survival in the first 3 weeks of life, this requirement diminishes as chicks mature (Johnson and Boyce 1990). Few primary forbs and insects were abundant at foraging locations of chicks at Hart Mountain. The most readily available forbs and insects usually were used only incidentally by chicks. Most primary foods were available in low (<5% frequency) amounts. In southeastern Oregon, the quality of brood use sites apparently was related to the abundance of primary foods (Drut 1992).

Prescribed Burning

Fall burning increased Cichorieae but burning had no apparent effect on most other primary foods including microsteris, desert-parsley, June beetles, and darkling beetles. Response observed for Cichorieae was supported by other studies that evaluated prescribed burning in mountain big sagebrush (Blaisdell 1953, Mangan and Autenrieth 1985). Additionally, Humphrey (1984) and Koniak (1985) modeled secondary succession after summer-fall wildfires and reported that annual and perennial Cichorieae were most prominent in early and mid succession stages (e.g., <20 years after fire).

Compared with fall treatments, spring treatments were more severe and, therefore, possibly reduced survival of Cichorieae, plants that have tap-roots and wind-dispersed seeds (Hitchcock and Cronquist 1973). Apparently, tap-roots can promote survival of mature plants by maintenance of dormant tissues below ground; wind-dispersed seeds can expedite dissemination and colonization (Laycock 1967, McLean 1969, Rowe 1983, Humphrey 1984). Previous authors indicated that plant response to prescribed burning was associated mainly with site factors, fire characteristics, and ecological traits of plants (Blaisdell 1953, Mueggler and Blaisdell 1958, Wright and Klemmedson 1965, Blaisdell et al. 1982).

Because few studies dealt with desert-parsley and microsteris, little information was available to substantiate observations at Hart Mountain. An evaluation of the literature revealed that response of desert-parsley to burning is undetermined. For microsteris, results from this study contrasted with findings from Idaho, where plants were evaluated in burns of different successional stages (Humphrey 1984). In Idaho, cover of microsteris was greatest on early seral sites, a response expected based on the species' annual growth-form and seed ecology (Evans and Young 1970, Humphrey 1984). At Hart Mountain, however, microsteris was not positively influenced by prescribed burning. Milkvetch, though not evaluated at Hart Mountain, was found to increase after fall burning but not spring burning in other studies (Mueggler and Blaisdell 1956, Kuntz 1982, Humphrey 1984).

June and darkling beetles apparently were not affected by prescribed burning. A similar response was reported in studies that removed Wyoming big sagebrush (_A_. _t_. _wyomingsis_) by prescribed burning or mechanical means (Parmenter and MacMahon 1984, Winter 1984). Persistence of June and darkling beetles after shrub removal was associated with maintenance of understory food and cover components, including forbs, grasses, and rabbitbrush (Parmenter and MacMahon 1984).

At the community level, total forb cover, perennial forb frequency, and perennial forb diversity increased after prescribed burning of sagebrush-bitterbrush at Hart Mountain. Total forb cover ranged from 13-15% on burned plots to 8% on unburned controls during the second growing season. Other studies reported that forbs showed the largest initial increase compared with grasses and shrubs after burning in mountain big sagebrush and associated communities (Blaisdell 1953, Mueggler and Blaisdell 1958, Harniss and Murray 1973).

Burned plots were dominated by native perennial bunchgrasses, whose relative composition increased to >50% of total vegetation cover in the second year of study. Other studies indicated that cover of native grasses gradually increased during early and mid succession after burning (Blaisdell 1953, Harniss and Murray 1973, Barney and Frischknecht 1974, Humphrey 1984, Wambolt and Payne 1986). Burned plots were not degraded by invasion of cheatgrass. However, cheatgrass can influence the outcome of succession on burned sites depleted of native perennial grasses (Young et al. 1972, Young and Evans 1973, Young and Evans 1978).

Prescribed burning at Hart Mountain seemingly reduced spiders and increased ants, wasps, and bees but had no influence on other orders of insects or insect diversity. Similar results were reported for the same taxa in Idaho, except that burning reduced bristletails (Thysanura), an order dependent on litter (Borror et al. 1981, Winter 1984). Results from Hart Mountain and other areas suggested that prescribed burning and shrub removal have no initial influence on grasshopper abundance, beetle abundance, and beetle diversity (Parmenter and MacMahon 1984, Winter 1984). Response of arboreal arthropods to burning was not evaluated in this study. In Idaho, however, burned sites supported more flies (Diptera), bugs (Hemiptera), plant hoppers (Homoptera), but fewer moths and butterflies (Lepidoptera) (Winter 1984).

Prescribed burning reduced total shrub cover, a primary factor that determines competitive interaction between forbs and shrubs (Tisdale et al. 1969, Harniss and Murray 1973, Winward 1991). Reduction in shrub cover was associated with increased forbs, including Cichorieae. In southeastern Oregon, the amount of primary forbs was associated with site use in the early brood-rearing period, but overall forb amount was associated with site use in the late-brood rearing period (Drut 1992). Consequently, fall-burned sites in this study, were perhaps most suitable to broods because amount of Cichorieae was increased and supply of other forbs and insects was maintained. Additionally, accessibility of forbs and insects to chicks possibly increased after shrub cover was reduced on fall and spring burned sites (Klebenow 1969, Hurst 1971, Klebenow 1972).

In this study, fire killed sagebrush, and therefore eliminated its availability as a food or cover source for broods on burned sites. Although prescribed burning eliminated sagebrush as a food source, sagebrush was available in close proximity to burned sites in addition to its wide distribution on the study area. Previous research of mountain big sagebrush indicated that it usually established on burned sites in 3 years and was a community dominant in 30 years (Blaisdell 1953, Harniss and Murray 1973). However, rate of sagebrush establishment can be affected by stand composition before burning, severity, pattern, and extent of burn, and land-use practices after burning (Pechanec et al. 1954, Harniss and Murray 1973, Blaisdell et al. 1982).

Fall and spring prescribed burning changed, but did not eliminate brood cover. Cover was altered from dominance by shrubs before burning to dominance by forbs, grasses, and resprouting shrubs after burning. Other studies disclosed that hens with broods foraged in a variety of habitats, including sites devoid of sagebrush (Savage 1969, Evans 1986). Sagebrush was, however, a principal component of habitat adjacent to foraging sites devoid of the shrub (Klebenow 1985). Consequently, because sage grouse broods require sagebrush for cover on a daily basis (Savage 1969, Dunn and Braun 1986), extensive sagebrush reduction by burning or other practices could reduce the value of these areas as foraging habitat (Martin 1970, Braun et al. 1977, Autenrieth et al. 1981, Swenson 1987).

MANAGEMENT IMPLICATIONS

Current management guidelines for sage grouse stress maintenance of meadows and sagebrush uplands for broods (Braun et al. 1977, Autenrieth et al. 1981). In uplands, manipulation of brood-rearing habitats is considered appropriate where (1) sagebrush communities are not limited in extent, (2) sagebrush exceeds 20% cover, and (3) adequate interspersion of treated and untreated areas can be maintained (Braun et al. 1977, Autenrieth et al 1981, Mangan and Autenrieth 1985). Additionally, the probability of increasing forb cover with shrub control is greatest in mountain big sagebrush and associated communities (Blaisdell et al. 1982, Bunting et al. 1987).

Evaluation of brood-rearing habitat should be based on several criteria including an understanding of the interaction between land-use practices and availability of primary foods of chicks. Fall and spring prescribed burning of dense sagebrush-bitterbrush stands did not significantly influence amounts of most primary insects and forbs available on burned sites. Although burning increased overall forb amount and habitat heterogeneity, its utility as a food enhancement practice may be limited because of reduction in sagebrush, which serves as both food and cover, and because of the inconsistent response to fire of primary foods.

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Appendix A. Aggregate mass (%) and frequency (%) of foods in the diet of sage grouse chicks, Hart Mountain, Oregon, 1988-89.

Forage class and taxon	Aggregate mass (%)	Frequency (%)
Forbs		
Astragalus lentiginosus	9.1	32
Microsteris gracilis	8.2	48
Agoseris glauca	6.8	27
Tragopogon dubius	5.3	11
Achillea millifolium	4.8	9
Astragalus filipes	4.5	20
Crepis acuminata	4.1	34
Taraxacum officinale	3.6	20
Agoseris heterophylla	3.4	11
A. grandiflora	3.1	9
Aster occidentalis	2.8	9
Erigeron corymbosus	2.4	16
Trifolium gymnocarpum	2.0	7
Astragalus purshii	2.0	11
A. obscurus	1.6	23
Lomatium nevadense	1.6	14
Mimulus nanus	1.1	2
Crepis modocensis	1.0	7
Gayophytum spp.	0.7	16
Fritillaria autropurpurea	0.5	5
Antennaria microphylla	0.5	11
Calachortus macrocarpus	0.4	5
Lactuca serriola	0.2	7
Descurainia sophia	0.2	5
Astragalus curvicarpus	0.2	5
Cleome platycarpa	0.1	5
Erigeron lonchophyllus	0.1	2
Trifolium cyathiferum	0.1	2
Collinsia parviflora	0.1	5
Phlox longifolia	0.1	9
Lomatium triternatum	0.1	5
Machaeranthera canescens	0.1	2
Total forbs	70.8	100
Shrubs		
Artemisia arbuscula	8.2	45
A. tridentata vaseyana	1.7	20
Ribes cereum	0.8	2
Artemisia tridentata tridentata	0.2	2
Total shrubs	11.0	59

Appendix A. (Continued)

Forage class and taxon	Aggregate mass (%)	Frequency (%)
Insects		
Diplotaxis tenebrosa	7.9	30
Coniontis proba	3.5	34
Okanagana occidentalis	2.0	7
Formica fusca	1.1	80
Chrysomelidae	0.4	11
Coccinella transversogutatta	0.4	13
Serica sp.	0.3	7
Dichelonyx backii	0.3	5
Emblethis vicarius	0.2	2
Alticinae	0.2	20
Carabidae	0.2	2
Lepidoptera	0.2	16
Hippodamia spp.	0.2	18
Limonius sp.	0.2	11
Stenocorus sp.	0.2	2
Lasius sp.	0.1	7
Lygaeus kalmii	0.1	7
Eleodes spp.	0.1	7
Geometridae	0.1	5
Hemicrepidius morio	0.1	5
Tenthredinidae	0.1	2
Curculionidae	0.1	9
Lepesoma sp.	0.1	7
Trachysida aspara	0.1	2
Membracidae sp.	0.1	2
Coccinellidae	0.1	7
Miridae	0.1	11
Total arthropods	18.2	95

Appendix B. Frequency (%) of foods at collection sites and aggregate mass (%) of foods in the diet of sage grouse chicks, Hart Mountain, Oregon, 1988-89.

Forage class and taxon	Collection sites Frequency (%) $\bar{x}$(SE)	Diet Aggregate mass (%) $\bar{x}$(SE)
Forbs		
Lupinus caudatus	8.3(2.4)	
Arenaria spp.	6.6(2.1)	0.8(0.8)
Epilobium spp.	5.9(1.8)	t
Phlox diffusa	5.5(1.8)	
Gayophytum spp.	4.4(1.2)	1.2(0.9)
Microsteris gracilis	3.9(1.8)	12.1(3.9)
Collinsia parviflora	3.8(2.3)	0.7(0.6)
Leptodactylon pungens	3.3(1.2)	
Astragalus obscurus	3.0(1.3)	3.9(1.9)
Polygonum douglassii	3.0(1.7)	
Collomia linearis	2.8(1.1)	
Eriogonum umbellatum	2.6(1.4)	
Naverretia intertexta	1.8(1.8)	
Senecio canus	1.8(0.7)	
Chenepodium album	1.7(1.1)	
Castilleja sp.	1.4(0.6)	
Agoseris glauca	1.2(0.4)	3.6(1.5)
Erigeron corymbosus	1.2(0.4)	2.2(1.1)
Phlox longifolia	1.1(0.6)	0.1(0.0)
Tragopogon dubius	0.8(0.4)	4.1(2.3)
Agoseris heterophylla	0.9(0.7)	2.7(1.3)
Crepis acuminata	0.7(0.4)	5.3(1.8)
Achillea millifolium	0.7(0.4)	1.2(0.9)
Astragalus filipes	0.7(0.4)	2.9(1.3)
A. lentiginosus	0.7(0.4)	6.7(2.3)
Lomatium nevadense	0.6(0.3)	3.4(1.8)
Agoseris grandiflora	0.4(0.4)	2.3(1.3)
Aster occidentalis	0.4(0.4)	1.4(0.8)
Astragalus purshii	0.4(0.3)	2.9(2.2)
Taraxacum officinale	0.4(0.2)	4.3(2.2)
Total forbs	53.8(3.8)	66.0(4.1)
Grasses	61.4(1.5)	0.1(0.1)
Sedges	7.3(1.8)	
Rushes	1.3(0.7)	
Shrubs[a]		
Artemisia tridentata[b]	7.8(1.8)	2.1(0.9)
A. arbuscula	7.4(1.2)	5.2(1.9)

Appendix B. (Continued)

Forage class and taxon	Collection sites Frequency (%) x(SE)	Diet Aggregate mass (%) x(SE)
Chrysothamnus nauseousus	1.4(0.6)	
Total shrubs	18.2(1.9)	8.0(2.2)
Arthropods[c]		
Formica fusca	96.4(1.5)	2.5(1.1)
Eleodes spp.	39.4(4.4)	0.2(0.1)
Pogonomyrmex sp.	34.4(5.9)	t
Coniontis proba	19.1(3.2)	5.5(1.6)
Calosoma luxatum	17.7(3.5)	
Camponotus vicinus	16.5(3.6)	
Centhophilus sp.	15.2(3.1)	
Harpalus sp.	14.7(3.6)	
Saprinus spp.	8.8(3.2)	
Pterostichus spp.	6.8(2.4)	
Steiroxys strepens	6.1(2.0)	
Emblethis vicarius	6.0(1.8)	t
Melanastus ater	5.8(1.8)	t
Solfugae	4.9(1.2)	
Scolopendromorpha	4.8(1.9)	
Limonius sp.	4.5(2.6)	0.2(0.1)
Diplotaxis tenbrosa	4.2(1.9)	8.4(2.9)
Gryllus sp.	3.5(1.5)	
Stenopelmatus fuscus	3.4(1.6)	
Trombidiidae spp.	2.7(1.5)	t
Serica sp.	2.5(1.0)	1.1(1.0)
Blapstinus oregonensis	2.2(1.1)	
Mutillidae	2.1(0.8)	
Tenebrionidae	2.1(1.5)	
Amara sp.	1.7(1.0)	t
Malezonotus sodalicus	1.5(1.0)	
Philonthus sp.	1.3(0.8)	
Lepesoma sp.	1.3(0.7)	t
Agonum sp.	1.1(0.6)	
Total arthropods[d]	99.4(0.4)	19.2(3.9)

[a]Assessment of shrubs at collection sites based on percentage cover.
[b]Artemisia tridentata vaseyana.
[c]Ground-dwelling taxa only.
[d]Use of arboreal taxa averaged 5.8(2.0).
t=less than 0.1% frequency at collection site or aggregate mass in diet.

Appendix C. Aggregate mass (%) of forbs consumed by 1-5 and 6-10 week-old sage grouse chicks, frequency (%) of forbs at collection sites of 1-5 and 6-10 week-old sage grouse chicks, and selection of forbs by 1-5 and 6-10 week-old sage grouse chicks, Hart Mountain, Oregon, 1988-89.

Age class and taxon	Aggregate mass (%) $\bar{x}$(SE)	Frequency (%) $\bar{x}$(SE)	Selection rank[a]
1-5 weeks (N=25)			
Microsteris (*Microsteris gracilis*)	20.0(6.4)	6.3(3.1)	-0.90 A
Nevada desert-parsley (*Lomatium nevadense*)	6.0(3.1)	0.8(0.5)	-0.62 A
Annual agoseris (*Agoseris heterophylla*)	4.7(3.2)	1.5(1.2)	-0.42 A
Freckled milkvetch (*Astragalus lentiginosus*)	3.0(2.0)	0.9(0.7)	-0.42 A
Common dandelion (*Taraxacum officinale*)	5.4(3.5)	0.6(0.4)	-0.28 A
Basalt milkvetch (*Astragalus filipes*)	2.6(1.9)	1.2(0.7)	-0.12 A
Arcane milkvetch (*A. obscurus*)	6.8(3.2)	4.8(2.2)	-0.12 A
Mountain dandelion (*Agoseris glauca*)	2.4(1.5)	1.5(0.7)	-0.08 A
Yellow salsify (*Tragopogon dubius*)	2.5(2.3)	0.9(0.7)	0.18 A
Other forbs	12.5(3.3)	49.1(5.3)	2.78 B
Total forbs	64.5(5.8)	56.1(5.1)	
6-10 weeks (N=19)			
Tapertip hawksbeard (*Crepis acuminata*)	11.9(3.7)	1.1(0.6)	-1.61 C
Freckled milkvetch (*Astragalus lentiginosus*)	11.0(4.4)	0.5(0.3)	-1.29 CD
Basalt milkvetch (*A. filipes*)	3.3(1.7)	0.1(0.1)	-0.50 CDE
Pursh's milkvetch (*A. purshii*)	6.8(4.9)	0.8(0.7)	-0.08 CDE
Long-leaf fleabane (*Erigeron corymbosus*)	5.0(2.3)	1.6(0.8)	0.24 CDE
Mountain dandelion (Agoseris glauca)	5.2(2.9)	0.9(0.5)	0.29 CDE
Microsteris (*Microsteris gracilis*)	1.7(1.2)	0.7(0.4)	0.42 DE
Yellow salsify (*Tragopogon dubius*)	6.1(4.3)	0.1(0.1)	0.63 E
Other forbs	16.8(3.8)	45.3(6.0)	1.89 F
Total forbs	68.1(5.4)	50.1(5.4)	

[a]Taxonomic categories with the same letter within column and age class were not different ($P > 0.05$).

Appendix D. Vegetal cover (%) in sagebrush-bitterbrush treatment areas before prescribed burning, Hart Mountain, Oregon, June-July 1987.[a]

	Treatment area			
Characteristic (%)	One $\bar{x}$(SE)	Two $\bar{x}$(SE)	Three $\bar{x}$(SE)	Four $\bar{x}$(SE)
Forb cover				
Annuals	0.8(0.3)	3.2(1.2)	1.2(0.5)	1.2(0.3)
Perennials	0.7(0.3)	0.9(0.2)	3.0(0.5)	9.3(2.4)
Total forbs	1.5(0.4)	4.2(1.1)	4.2(0.5)	10.4(2.2)
Grass cover				
Annuals	3.6(2.2)	7.4(3.3)	9.7(3.0)	3.1(2.1)
Perennials	11.0(1.1)	12.0(2.8)	16.4(1.5)	14.2(1.1)
Total grasses	14.6(1.2)	19.4(2.9)	26.2(2.6)	17.1(1.6)
Shrub cover				
Sagebrush-bitterbrush	34.4(6.5)	46.1(6.2)	30.2(4.8)	22.6(5.0)
Total shrubs	36.1(7.2)	52.9(5.6)	45.0(3.4)	46.2(2.1)

[a]Cover assessment comprised 6 transects of 216 points/treatment area by the point-intercept procedure (Floyd 1982).

Appendix E. Cover (%) of forbs after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row and year were not different P > 0.05 (LSD test).

	1988			1989		
Vegetal class and taxon (%)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Annuals						
Collinsia parviflora	1.1(0.1)A	0.7(0.2)A	0.1(0.1)B	0.9(0.5)D	1.7(0.6)E	2.6(0.5)F
Collomia linearis	--	--	0.2	0.2	--	0.6
Descurainia sophia	--	--	--	--	0.4(0.4)	0.6(0.2)
Gayophytum sp.	0.1(0.1)	--	--	0.2(0.1)	--	0.4(0.2)
Microsteris gracilis	0.3(0.1)	0.1(0.1)	0.0(0.0)	0.9(0.3)	0.3(0.3)	0.6(0.4)
Polemonium micranthum	--	--	--	0.4	0.7	0.4
Perennials						
Agoseris glauca[a]	0.3(0.1)	1.5(0.6)	0.9(0.3)	0.4(0.2)	1.5(0.9)	1.3(0.6)
Allium hookeri	1.9	0.2	0.8	0.6	0.2	1.3
Astragalus curvicarpus	0.6	--	1.0	2.5	--	1.9
Crepis acuminata[a]	0.3(0.2)	1.1(0.6)	0.9(0.4)	0.8(0.3)	2.1(0.7)	1.5(0.6)
Erigeron corymbosus	0.8(0.8)	0.2(0.2)	1.0(0.8)	0.5(0.4)	0.6(0.6)	1.8(1.0)
Lithospermum ruderale	0.4(0.2)	1.1(0.1)	0.6(0.6)	0.4(0.2)	1.4(0.1)	1.9(1.3)
Lomatium nevadense	0.9(0.4)	0.5(0.5)	0.5(0.5)	0.9(0.3)	1.5(1.1)	0.8(0.6)
L. triternatum	--	0.6	--	0.3	1.5	0.4
Lupinus caudatus	0.1(0.1)	0.9(0.7)	0.3(0.1)	0.2(0.2)	1.7(0.2)	0.8(0.5)
Phlox longifolia	0.3	--	0.4	0.3	--	0.4
Senecio canus	2.1	0.4	1.3	0.4	1.5	4.0
S. integerimmus	2.1	4.6	1.0	1.3	4.0	3.8
Viola nuttallii	0.4	0.4	2.9	--	0.2	0.6
Zigadenus paniculatus	0.2	0.2	0.4	--	--	--

[a]Treatment effect and block x treatment interaction were significant P < 0.05 (2-way ANOVA).

Appendix F. Frequency (%) of forbs after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row and year were not different $P > 0.05$ (LSD test).

Vegetal class and taxon (%)	1988 Control x(SE)	1988 Fall burn x(SE)	1988 Spring burn x(SE)	1989 Control x(SE)	1989 Fall burn x(SE)	1989 Spring burn x(SE)
Annuals						
Arabis spp.	7(5)	5(5)	0(0)	7(5)	6(4)	7(5)
Collinsia parviflora	58(11)A	27(12)B	0(0)C	64(8)	74(8)	76(3)
Collomia linearis	8	44	--	44	42	73
Descurainia sophia	--	--	--	--	4	25
Gayophytum sp.	8(3)A	4(2)A	1(1)B	19(5)	15(9)	33(6)
Microsteris gracilis	42(6)A	22(6)B	0(0)C	80(6)	65(10)	48(12)
Montia perfoliata	8(4)	4(2)	--	19(4)	39(13)	49(14)
Polemonium micranthum	4	1	3	44	44	32
Polygonum douglassii	--	8	--	6	31	10
Perennials						
Agoseris glauca	45(10)	67(1)	48(10)	49(7)	75(2)	63(5)
Allium hookeri	67	58	52	85	81	65
Calachortus macrocarpus[a]	2(1)	1(1)	2(1)	1(1)	3(1)	5(1)
Crepis acuminata[a]	6(3)	15(7)	20(7)	6(3)	17(9)	20(7)
Astragalus curvicarpus	13	4	21	23	15	28
Delphinium andersonii	6	15	29	13	25	31
Erigeron corymbosus[a]	9(8)	7(7)	6(4)	11(8)	9(9)	8(6)
Fritillaria autropurpurea	--	--	--	4	14	8
Lithospermum ruderale[a]	4(3)	6(2)	9(3)	5(4)	7(3)	13(3)
Lomatium nevadense[b]	34(14)	38(15)	31(17)	45(12)	49(19)	36(15)
L. triternatum	--	15	10	2	50	27
Lupinus caudatus	3	16	17	5	25	15
Phlox longifolia[a]	4(0.7)	16(3)	12(8)	2(0.0)	16(1)	10(6)
Senecio canus	17	23	40	21	21	40
S. integerimmus	35	58	25	50	73	27
Viola nuttallii	33	40	60	44	30	79
Zigadenus paniculatus	8	8	--	8	--	--

[a]Treatment effect and block x treatment interaction were significant $P < 0.05$ (2-way ANOVA).
[b]Block x treatment interaction was significant $P < 0.05$ (2-way ANDVA).

Appendix G. Cover (%) of graminoids after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row and year were not different $P > 0.05$ (LSD test).

Vegetal class and taxon (%)	1988			1989		
	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Annuals						
Bromus tectorum	7.7(2.5)	4.1(0.9)	1.8(1.2)	3.8(1.2)	6.6(1.2)	3.1(1.3)
Perennials						
Agropyron spicatum	--	0.2	0.4	0.2	--	2.5
Bromus carinatus	1.5	1.9	--	--	2.1	0.4
Carex spp.	0.6	0.4	0.6	--	0.2	0.8
Elymus cinereus	0.9	--	1.0	0.6	0.8	1.0
Festuca idahoensis[a]	5.9(3.7)	0.9(0.3)	0.7(0.5)	7.6(3.9)	2.7(1.0)	2.6(1.2)
Koeleria cristata	--	--	--	0.5(0.5)	0.1(0.1)	1.0(0.4)
Poa spp.[a]	7.2(1.8)	5.9(1.3)	3.0(0.3)	7.8(1.3)	6.9(1.1)	4.0(0.6)
Sitanion hystrix	6.1(1.6)	4.8(1.3)	6.1(1.6)	7.6(3.3)	7.6(0.3)	11.1(2.6)
Stipa thurberiana[b]	1.7(0.5)	1.7(1.0)	1.1(0.7)	1.2(0.6)	1.6(0.6)	1.8(1.3)

[a]Treatment effect and block x treatment interaction were significant $P < 0.05$ (2-way ANOVA).
[b]Block x treatment interaction was significant $P < 0.05$ (2-way ANOVA).

Appendix H. Frequency (%) of graminoids after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row and year were not different P > 0.05 (LSD test).

	1988			1989		
Vegetal class and taxon (%)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Annuals						
Bromus tectorum[a]	78(11)	74(13)	40(7)	77(6)	72(10)	57(8)
Perennials						
Agropyron spicatum	--	2	4	--	--	--
Bromus carinatus	8	27	--	--	19	--
Carex spp.	17	6	8	19	6	21
Elymus cinereus	4	4	4	6	4	2
Festuca idahoensis	14(12)	22(12)	20(9)	14(7)D	20(1.0)E	18(2)D
Koeleria cristata	1(1)	5(2)	1(1)	1(1)	3(2)	2(2)
Melica fugax	--	8	--	--	4	--
Poa spp.	62(9)	67(11)	50(6)	77(2)	74(10)	62(9)
Sitanion hystrix	36(7)	40(8)	48(10)	53(16)	47(12)	50(14)
Stipa thurberiana	19(4)	19(3)	21(5)	6(3)	10(6)	10(5)

[a]Treatment effect and block x treatment interaction were significant P < 0.05 (2-way ANOVA).

Appendix I. Shrub cover (%), density of bitterbrush (seedlings/m^2), and frequency (%) of bitterbrush resprouting after fall and spring prescribed burning, Hart Mountain, Oregon, 1989. Treatment means with no letter or the same letter within row were not different P > 0.05 (LSD test).

Chaaracteristic	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Cover (%)			
Sagebrush	13(5)A	0(0)B	0(0)B
Bitterbrush	15(4)A	2(1)B	1(1)B
Rabbitbrush	3(2)	4(3)	3(2)
Total shrubs	35(4)A	11(4)B	5(3)B
Density (seedlings/m^2)			
Bitterbrush	0.4(0.2)	1.6(1.0)	1.6(0.6)
Resprout frequency (%)			
Bitterbrush	--	28(7)	29(13)

Appendix J. Abundance (no/trap) of arthropods after fall and spring prescribed burning, Hart Mountain, Oregon, 1988-89. Treatment means with no letter or the same letter within row and year were not different P > 0.05 (LSD test).

	1988			1989		
Order, family, and genus (%)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Araneida	12.5(1.1)	8.1(1.9)	7.8(2.2)	6.9(0.9)D	4.3(0.3)E	4.2(0.6)E
Coleoptera						
Agyrtidae						
Apteroloma	0.3	0.1	0.1	0.2	0.5	0.1
Anthicidae						
Notoxus	0.2	0.1	--	--	--	--
Carabidae						
Amara	0.03	0.1	0.1	0.1	0.1	0.4
Carabus	1.5(0.6)A	0.04(0.04)AB	0.03(0.02)B	0.7(0.3)	0.02(0.02)	0.0(0.0)
Harpalus	0.6(0.2)A	1.7(0.4)B	0.8(0.2)A	0.7(0.3)	1.0(0.4)	0.9(0.6)
Cerambycidae						
Stenocorus	--	0.1	0.2	--	--	--
Trachysida	--	0.3	0.3	--	--	0.2
Chrysomelidae						
Trichochrous	0.2(0.1)	0.2(0.2)	0.02(0.02)	0.1(0.1)	0.1(0.1)	0.1(0.04)
Coccinellidae						
Hyperaspis	0.1	--	0.1	--	--	--
Seymus	0.2(0.2)	0.02(0.02)	0.03(0.02)	0.0(0.0)	0.02(0.02)	0.02(0.02)
Curculionidae						
Dyslabus	--	0.1	0.2	--	0.1	0.1
Hypera	0.04(0.03)	0.1(0.1)	0.1(0.1)	0.1(0.02)	0.1(0.02)	0.2(0.1)
Elateridae						
Limonius	0.1	0.2	1.7	--	0.1	0.3
Histeridae						
Saprinus[b]	0.1(0.04)	0.02(0.02)	0.1(0.03)	0.03(0.03)	0.02(0.02)	0.1(0.02)
Lucanidae						
Platycerus	0.1(0.04)	0.02(0.02)	0.1(0.03)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Scarabaeidae						
Glaresis	0.1	0.2	0.1	--	--	--
Serica	0.3	0.3	1.1	0.1	0.3	0.7

Appendix J. (Continued)

Order, family, and genus (%)	1988			1989		
	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)	Control $\bar{x}$(SE)	Fall burn $\bar{x}$(SE)	Spring burn $\bar{x}$(SE)
Silphidae						
Nicrophorus	0.03	0.03	0.5	0.1	--	0.4
Staphylinidae						
Philonthus	0.02(0.02)	0.1(0.04)	0.1(0.03)	0.02(0.02)	0.1(0.04)	0.0(0.0)
Tachinus	0.1(0.05)	0.1(0.1)	0.4(0.2)	0.1(0.04)	0.1(0.1)	0.1(0.02)
Tenebrionidae						
Coniontis	0.6(0.2)	0.3(0.2)	0.2(0.1)	0.4(0.1)	0.3(0.2)	0.2(0.1)
Eleodes[a]	2.4(0.4)	1.7(0.4)	1.9(0.5)	1.8(0.4)	1.4(0.6)	2.1(0.7)
Diptera						
Acroceridae						
Eulonchus	0.5(0.2)	0.3(0.1)	0.6(0.2)	0.1(0.04)	0.03(0.03)	0.0(0.0)
Anthomyzidae	0.9(0.2)	0.8(0.1)	1.5(0.7)	1.4(0.5)	0.9(0.4)	0.7(0.2)
Chloropidae	0.7	0.7	0.5	--	--	--
Mycetophilidae	0.2(0.1)	0.3(0.04)	0.1(0.05)	0.02(0.02)	0.02(0.02)	0.03(0.03)
Tachinidae	0.1(0.04)	0.1(0.1)	0.02(0.02)	0.1(0.1)	0.1(0.04)	0.2(0.1)
Tipulidae	0.2(0.1)	0.2(0.2)	0.3(0.1)	0.6(0.3)	1.2(0.9)	0.4(0.1)
Heteroptera						
Lygaeidae						
Emblethis	0.1	--	--	--	0.1	0.1
Geocoris	0.1(0.04)	0.1(0.1)	0.5(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Other lygaids	0.3(0.1)	0.2(0.02)	0.2(0.1)	0.02(0.02)	0.0(0.0)	0.0(0.02)
Reduviidae						
Pselliopus	0.03(0.02)	0.0(0.0)	0.03(0.02)	0.1(0.02)D	0.0(0.0)E	0.03(0.02)DE
Thyreocoridae						
Corimelaena	0.1	0.1	0.5	--	--	0.1
Hompotera						
Cicadellidae	2.3(0.4)	2.3(0.6)	1.9(0.6)	1.0(0.3)	1.2(0.5)	0.8(0.3)
Hymenoptera						
Formicidae						
Camponotus	1.1(0.7)	1.7(0.8)	0.8(0.5)	0.9(0.6)	1.8(1.1)	1.2(0.5)
Formica[a]	21.2(7.0)	74.6(47.1)	58.8(14.1)	13.4(2.9)	55.8(42.1)	40.6(25.2)

Appendix J. (Continued)

Order, family, and genus (%)	1988 Control x̄(SE)	1988 Fall burn x̄(SE)	1988 Spring burn x̄(SE)	1989 Control x̄(SE)	1989 Fall burn x̄(SE)	1989 Spring burn x̄(SE)
Myrmicinae	2.2(0.6)	5.0(1.5)	4.7(1.9)	0.6(0.4)	1.1(1.1)	0.8(0.4)
Halictidae	0.1(0.02)	0.1(0.1)	0.4(0.2)	0.1(0.03)	0.1(0.04)	0.03(0.02)
Pompilidae	0.2(0.02)	0.1(0.06)	0.1(0.05)	0.2(0.1)	0.1(0.04)	0.1(0.04)
Sphecidae	0.02(0.02)	0.02(0.02)	0.1(0.02)	0.02(0.02)	0.02(0.02)	0.0(0.00)
Lepidoptera	0.3(0.04)A	0.1(0.02)B	0.1(0.04)B	0.5(0.04)	0.4(0.1)	0.60(0.1)
Caterpillars	0.1(0.02)	0.1(0.1)	0.1(0.1)	0.1(0.1)	0.2(0.2)	0.1(0.05)
Gelechiidae	0.0(0.0)A	0.0(0.0)A	0.1(0.02)B	0.0(0.0)	0.0(0.0)	0.1(0.1)
Noctuidae						
Orthoptera	0.1(0.04)	0.2(0.04)	0.3(0.1)	0.2(0.03)	0.1(0.0)	0.3(0.1)
Acrididae						
Gryllacrididae	1.4(0.5)	3.3(1.3)	3.2(1.2)	0.5(0.2)D	1.4(0.4)DE	1.8(0.4)E
Centhophilus	0.1(0.04)	0.3(0.3)	0.4(0.2)	0.1(0.1)	0.1(0.0)	0.1(0.04)
Stenopelmatus						
Tettigonidae	0.9(0.4)	0.2(0.1)	0.1(0.03)	0.2(0.1)	0.1(0.04)	0.2(0.1)
Steiroxys						
Scolopendromorpha	0.1	0.1	0.4	--	0.1	0.2
Solfugae	0.03(0.02)	0.04(0.04)	0.1(0.03)	0.1(0.1)	0.1(0.02)	0.2(0.03)
Thysanura	14.0(4.7)	6.4(2.8)	3.5(2.6)	20.4(13.8)	13.5(2.9)	9.0(3.3)

[a]Treatment effect and block x treatment interaction were significant $P < 0.05$ (2-way ANOVA).
[b]Block x treatment interaction was significant $P < 0.05$ (2-way ANOVA).