Effect of Livestock Grazing and Fire History on Fuel Load in Sagebrush-Steppe Rangelands

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Abstract

Managers face an important and challenging task of measuring, modeling, and managing wildfire risk. We examined the effect of livestock grazing and previous wildfire events on fuel load in southeastern Idaho as part of a wildfire risk-livestock interaction study. Fuel load was estimated using ordinal fuel load classes at 128 sample sites stratified by current livestock grazing and documented wildfire occurrence (1939-2000). Fifty-nine percent of previous wildfire sites ($n = 46$) had a documented fire within the past 2 years. Livestock grazing was the most effective means to reduce fuel load ($P < 0.0005$) compared to recent wildfire ($P < 0.05$) and livestock grazing with previous wildfire ($P < 0.05$) at higher stocking rates (1 AU / 19.8ha). Fire, on the other hand, was more effective compared to lower stocking rates (1 AU / 34.6ha). When proper consideration is given to other ecological effects, livestock grazing provides a viable management tool for fuel load reduction that avoids the negative effect of extreme fire intensity where fuel load is high.

Keywords: Idaho, fuel load, livestock grazing, wildfire

Introduction

There has been a critical need to predict and manage rangeland wildfire danger since the 1940s (Burgan and Shasby 1984, Burgan et al. 2000). Various studies have been conducted to measure fuel load and model fire behavior (Deeming et al. 1977, Anderson 1982, Andrews and Bradshaw 1997) although others have determined the effect of various vegetation treatments on fuel load (Madany and West 1983, Tsiouvaras et al. 1989, Blackmore and Vitousek 2000).

Litter, percent bare-ground, vegetation composition, structure, and senescence are important components in estimating fuel load (Anderson 1982). Fuel load models have become a valuable tool for predicting fire behavior (Anderson, 1982) and managing wildfire risk. Various methods exist to estimate fire risk, including the National Fire Danger Rating System (Deeming et al. 1977, Bradshaw et al. 1984) and the Wildland Urban Interface fire risk model (Weber et al. 2002). Understanding factors that influence fuel load is also of value particularly when management alternatives could be implemented to reduce fuel load and wildfire risk. We examined the effect of livestock grazing and previous wildfire on fuel load levels in sagebrush-steppe rangelands of southeastern Idaho to determine the effect of these treatments on current fuel-load levels.

Study Area

This study was conducted on land managed by the USDI Bureau of Land Management (BLM), Upper Snake River District in southeastern Idaho. Sample points were located between 43°36'00"N and 42°48'00"N latitude and -113°35'00"W and -112°37'59"W longitude. This area is sagebrush-steppe semi-desert, with a history of livestock grazing and wildfire. The study area can be typified as having fairly high-bare ground exposure (~25-50% exposure of

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thin, wind-blown loess soils) with frequent volcanic rock outcrops. Common shrubs include Wyoming big sagebrush (*Artemisia tridentata wyomingensis*), green rabbitbrush (*Chrysothamnus viscidiflorus*) and rubber rabbitbrush *(C. nauseosus*), and antelope bitterbrush (Purshia tridentata). The most common grasses are cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), and bluebunch wheatgrass (A. spicatum). Currently, both sheep and cattle graze this area. Deferred, rest-rotation, and continuous/seasonal grazing systems are used in the study area on allotments that range in size from 1153 to 128,728 ha (Table 1). The actively-grazed allotments used in this study (Big Desert and Twin Buttes) were both sheep allotments having stocking rates of 19.8 and 34.6 ha/AU, respectively.

Materials and Methods

We estimated Fuel load during summer 2001 at 128 sample points randomly located across the study area (Fig. 1). Fuel load estimation followed BLM procedures (Anderson 1982). Each point was located ≥ 70 m from roads and other mapped features, e.g., fence lines, to avoid edge effects. We stratified sample points by grazing treatment (grazed vs. ungrazed) and fire history. Fire history was determined using an historical wildfire (1939-2000) GIS data set with samples categorized into no-fire, one- fire, or multiple-fire treatment classes (Table 1). We determined grazing treatment from grazing allotment data provided by the BLM. Each allotment was attributed as either being grazed (1) or not grazed (0).

Field observations were made within an area approximately 900 m2 in size (the area occupied by 1, 30 x 30 m Landsat pixel) centered over each sample point. Our fuel load estimates followed "Field Survey Project for Fuels Management Planning GIS Mapping Standards" (USDI Bureau of Land Management 2001) and Anderson (1982). Visual estimates made at each sample point included: (1) fuel load, (2) presence/absence of live fuels, (3) percent bare ground, and (4) percent cover of shrubs, grasses, and forbs.

After visually inspecting the sample site, technicians determined fuel load by comparing their observations with Fire Behavior Fuel Model descriptions provided in Anderson (1982) that enumerated thirteen fuel model groups having fuel loads ranging from 1659 kg/ha (0.74 tons/acre)(grass group model 1) to 130260 kg/ha (58.1 tons/acre; logging slash group model 13). The fuel load class that best fit field observations was selected and used as the fuel load estimate. Within the study area, only 5 fuel load classes were observed (< 2242 kg/ha [< 1 tons/acre], 2242-4484 kg/ha [1-2 tons/acre], 4484-8968 kg/ha [2-4 tons/acre], 8968-13452 kg/ha [4-6 tons/acre], and >13452 kg/ha [>/6 tons/acre]).

We determined percent bare ground and percent vegetative cover for all shrub, grass, and forb vegetation types using ocular estimation and nine cover classes (none, 1-5%, 6-15%, 16-25%, 26-35%, 36-50%, 51-75%, 76-95%, and >95%). Percent cover was estimated with observers looking straight down to eliminate estimation errors due to an orthogonal perspective. This procedure was used because this study was part of a larger remote sensing research project requiring collection of numerous cover class estimates (~ 300) each field season. The area assessed at each point was approximately 4.8 m2. Estimated cover class was validated against empirical cover calculations and found to agree well when cover classes were utilized (McMahan et al. 2003).

Each sample point was classified into

Table 1. Stocking rate and grazing system appied in allotments assessed for this study.

	Stocking Rate		Season of Use				
Allotment	**(HA/ AU)**	**HA**	**Spring**	**Summer**	**Fall**	**Winter**	**Grazing Systems**
Big Desert	19.8	95,653	YES	NO	YES	YES	Continuous
Twin Buttes	34.6	109,588	YES	NO	YES	NO	Continuous

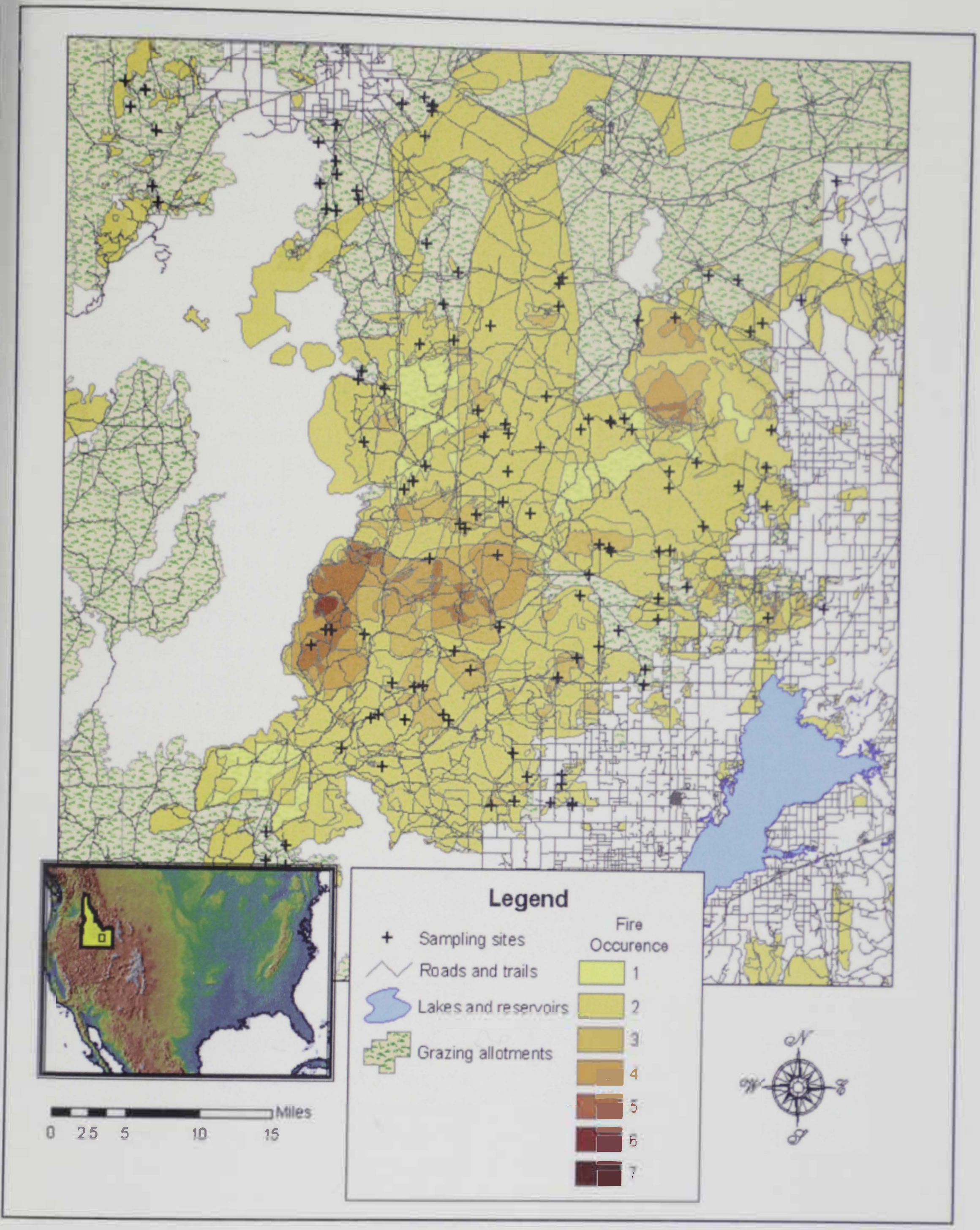

Fig. 1. Sample locations, public land grazing allotments, and fire occurrence (1939-2000) for the study area.

four categories representing the treatment type(s) found at that site: 1) grazed with previous wildfire, 2) grazed without previous wildfire, 3) no grazing with previous wildfire, and 4) no grazing or previous wildfire (i.e., control). Grazing was further stratified into two relative categories; 1) high stocking rate (19.8 ha/AU) and 2) low stocking rate (34.6 ha/AU). A "previous wildfire" is one having occurred within the past 60 years, although most (59%) areas have had a fire in the past two years. Using these four categories, we tested the effect of grazing and wildfire treatments on fuel load using factorial ANOVA. We recognize the ordinal nature of our data violates the assumptions of both homogeneity of variance and normality. However, ANOVA is robust to these violations (Zar 1998) and should be fairly robust to a violation in homoscedasticity since each treatment contained approximately equal sample size. To further address these violations, we applied non-parametric Kruskal-Wallis and Mann-Whitney U with Bonferroni correction. While these non-parametric tests may have provided greater confidence and reliability in our results, they did not allow us to assess the interaction among treatments. For this reason, we examined the results from both factorial ANOVA and non-parametric tests.

Results

Of 13 possible fire behavior fuel models we encountered three (types 1, 2, and 6) in the field (Anderson 1982). Fire behavior fuel models one and two belonged to the grass group, while model six belonged to the shrub group. The models used in this study correspond with National Fire Danger Rating System models of "annual" and "perennial" grasses, and "sagebrush/grass" and "inter. brush" shrub models (Deeming and Brown 1975, Deeming et al. 1977). Five ordinal fuel load classes were described during field sampling in the summer of 2001 (Table 2).

Grasses were the dominant fuel load component (> 50% grass cover in all grazed areas and 26-35% grass cover in ungrazed burned areas) in all treatment types except the control, where shrubs were the dominant fuel load component (36-50% shrub cover; Table 3). Grazed areas consistently had a higher percent grass cover (> 51%, $n = 49$)

Table 2. Stratification of sampling points by treatment.

Treatment	Wildfire Occurence (1939-2000)			
	0	1	>1	Total
Grazed	16	13	20	49
Ungrazed	34	28	17	79
Total	50	41	37	128

compared to ungrazed areas (26-35%, n = 79).

Seventy-eight sample points were in areas of previous wildfire. The mean number of years since a fire was 16.3 years (Fig. 2) with most sites ($n = 46$) having a fire in the previous 2 years. The remaining sample sites ($n = 50$) had no record or indication of a wildfire since 1939. Mean fuel load was 1.34 kg ha-1 ($n = 44$) in all areas with a wildfire in the past 2 years, 1.59 kg ha-1 ($n = 19$) in non-grazed areas with a wildfire in the past 2 years, and 1.25 kg ha-1 ($n = 27$) in grazed areas with a wildfire in the past 2 years.

Fuel load was decreased significantly by previous wildfire and/or grazing treatment (Fig. 3). The most significant treatment effect, however, was grazing ($P < 0.0005$). The effect of grazing and previous wildfire on fuel load was significant ($P < 0.05$) as was the effect of fire alone ($P<0.01$) and the effect of grazing alone ($P < 0.01$). Non-parametric Kruskal-Wallis analysis revealed a significant difference in fuel load among the four treatments and control categories ($P<0.00005$). A post-hoc non-parametric Mann-Whitney U test with Bonferroni correction was used to evaluate the effect of each treatment on fuel load. Once again,

Table 3: Ordinal fuel load categories and associated fire behavior models

	Fuel Model Descriptions (Anderson 1982)		
	Grass group		Shrub group
Fuel load class	Model 1	Model 2	Model 6
1 (<2242 kg ha^{-1})	X		
2 (2242-4484 kg ha^{-1})	X	X	
3 (4484-8968 kg ha^{-1})	X	X	
4 (8968-13,452 kg ha^{-1})		X	
5 (>13,452 kg ha^{-1})			X

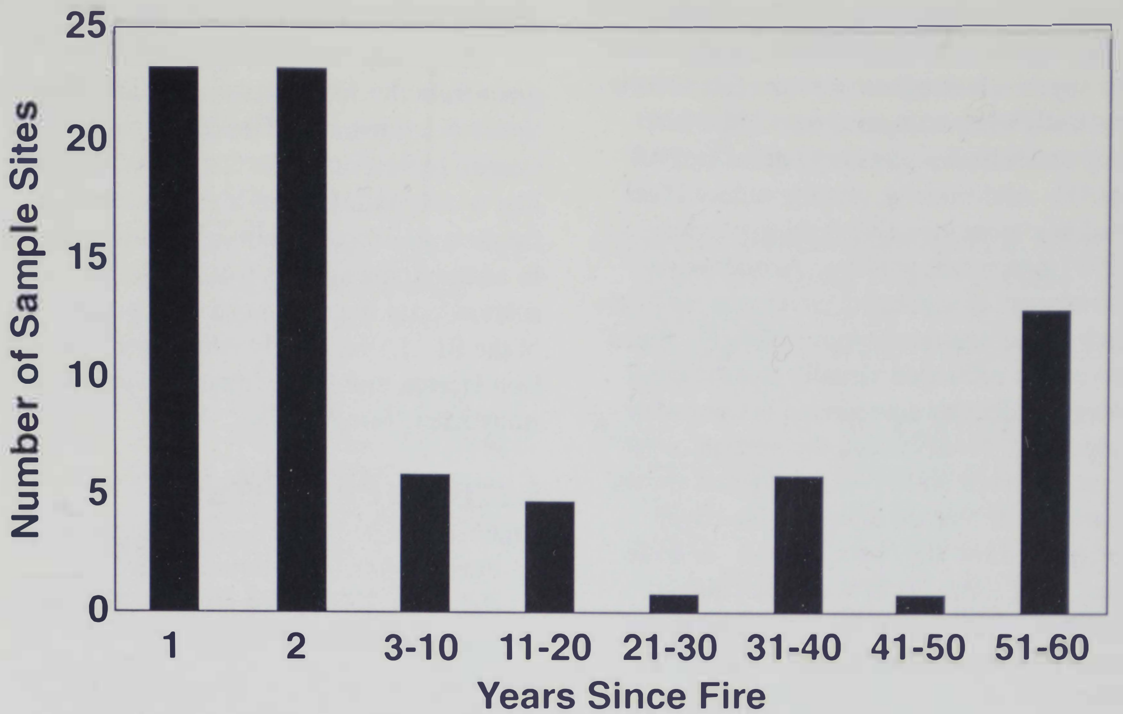

Fig. 2. The number of years since a fire occurrence at sampling sites (1939-2000). Mean years since fire = 16.3. Fifty sample sites had not burned during this period (>60 yrs.).

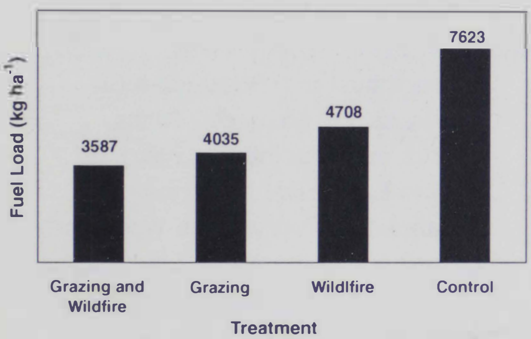

Fig. 3. Mean fuel load (kg ha-1) by treatment type. Fuel load estimations are from field observations.

a significant effect was observed for both grazing ($P < 0.01$) and fire ($P < 0.01$) treatments. However, when tested against the effect of fire with grazing, fire alone did not produce significant results ($P = 0.84$).

We further explored the effect of stocking rate as a covariate of grazing. However, since there were only two stocking rates applied within grazed allotments (19.8 ha/AU, and 34.6 ha/AU), stocking rate could not be treated as a statistical covariate. For this reason we ran an ANOVA with two between-subjects factors. The results indicate that at higher stocking rates (19.8 ha/AU) grazing was the most effective means to reduce fuel load. At lower stocking rates (34.6 ha/AU) fire was more effective ($P = 0.006$). Both the Big Desert and Twin Butte allotments were considered continuously grazed. However, both were grazed in the spring and fall by sheep during the period of this study.

Discussion

Historic fire suppression efforts have interrupted the natural fire cycle allowing fuel loads to reach unprecedented levels. Recent catastrophic wildfires, such as those seen in Idaho, Montana, Colorado, and Arizona have the potential to produce extremely intense and severe burns. While these fires reduce fuel load, they may also sterilize soils (Wells et al. 1979). These extensive fires may result in loss of biodiversity and the destruction of critical habitat for native plants and animals, which often leads to invasion by cheatgrass and other invasive species.

This study examined the effect of and interaction between two fuel load reduction treatments (livestock grazing and fire). We found livestock grazing to be as effective in reducing the primary fuel load component of the sagebrush-steppe ecosystem (herbaceous material) when compared to wildfire but only under higher stocking rates, i.e., 19.8 ha/AU. Additionally, grazing reduced fuel load in a more selective fashion (Archer 1999) than recent wildfire. A qualitative assessment of vegetative cover was made in each of the treatment types (Table 4). Since cover was estimated visually and recorded categorically this comparison is somewhat subjective. Nonetheless, the median cover class observed within each treatment shows nearly no difference in vegetation cover except in those sites being rested. In these sites, total shrub cover was much higher (median cover class = 36-50%) than in the other treatments (median cover class = 1-5%).

Studies in other regions have reported results that corroborate well with our findings. Within montane forests of Zion National Park, Madany and West (1983) considered livestock grazing the primary factor in the reduction of herbaceous cover. Tsiouvaras et al. (1989) reported that grazing by goats effectively reduced 1- and 10-hr fuel load in coastal forest areas of California. Similarly, Blackmore and Vitousek (2000) found grazing in dry forest ecosystems of Hawaii to be an effective means to reduce continuity of fuels, fire intensity, and fire risk. We view livestock grazing as a viable land management tool for fuel load reduction prescriptions when proper consideration has been given other ecological issues that we did not discuss in this paper.

In this study, we examined the effect of livestock grazing and previous wildfire on fuel load levels within sagebrush-steppe rangelands of southeastern Idaho. The results demonstrate that fuel load is most effectively reduced under relatively high stocking rates (19.8ha/AU). However, relatively low stocking rates (34.6ha/AU) failed to produce the same reduction in fuel load. In such a case, previous fires had a more substantial fuel load reduction effect.

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