2004 Annual Progress Report: Stratton Sagebrush Hydrology Study Area: Establishment of a Long-Term Research Site in a High-Elevation Sagebrush Steppe

By Kate Schoenecker, Bob Lange, and Mike Calton

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Goals

In 2004 the U.S. Geological Survey, Fort Collins Science Center (FORT) and the Bureau of Land Management (BLM), Rawlins Field Office (RFO), began a cooperative effort to reestablish the Stratton Sagebrush Hydrology Study Area (Stratton) as a research location, with the goal of making it a site for long-term research on sagebrush (Artemisia spp.) ecology. No other long-term research sites in high-elevation sagebrush habitat currently exist, and the Stratton area, with its 30+ year history of research and baseline data, was a logical location to restart investigations aimed at answering pertinent and timely questions about sagebrush ecology and sagebrush-obligate species. During the first year of the study, USGS scientists conducted an in-depth literature search to locate publications from research conducted at Stratton. We contacted previous researchers to acquire literature and unpublished reports of work conducted at Stratton. Collated papers and published manuscripts were presented in an annotated bibliography (Burgess and Schoenecker, 2004).

A second goal was to establish Stratton as a host location for researchers interested in sagebrush ecology investigations. We contacted staff and professors from Colorado State University and Wyoming and Montana universities to notify them of the opportunities at Stratton. Several institutions showed interest in the area and the potential of such a research site. A major advantage of the Stratton site is the ability of BLM to coordinate activities on the land, manipulate grazing in cooperation with permit holders, and direct other activities to accommodate appropriate long-term experimental designs.

A third goal was to evaluate grazing management after a prescribed burn. The BLM widely uses prescribed burns as a tool for land management and grazing management. In general, BLM policy restricts grazing after a wildfire for two or more years. Some BLM offices allow no grazing after a wildfire or prescribed treatment for at least two years. Conversely, the RFO often allows grazing following a prescribed burn directly after the peak growing season the following year. This procedure is used for two years post-burn, after which grazing management is directed by local

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conditions and goals. We are investigating this practice to evaluate the effects on plant production and nutrient cycling. The RFO specifically wants to know if there are negative effects from grazing one season after a prescribed burn.

Objectives

Our objectives were to 1) establish Stratton as a controlled site where long-term research on sagebrush ecology could be conducted, 2) organize past research at Stratton to add to the body of knowledge about sagebrush ecosystems, and 3) help current investigators focus their studies and evaluate grazing regimes and grazing management after a prescribed burn.

Study Area

Stratton is approximately 2,832 ha (7,000 acres) and is located 29 km west of Saratoga in southcentral Wyoming. The terrain is gently rolling, with 100 m of relief occurring between ridgetops and valley bottoms. The average elevation is 2400 m. The area receives 500 mm of precipitation annually, two-thirds of which falls as snow. Shrub vegetation includes mountain big sagebrush (*A. tridentata* ssp. *vaseyana*), black sagebrush (*A. nova*), Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) and sparse bitterbrush (*Purshia tridentata*). These shrubs predominate on the slopes and are interspersed with herbaceous vegetation. Several creeks run through the study area with a grass-forb vegetation component along streams. The study area is grazed by cattle and native ungulates, which include pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and occasionally elk (*Cervus elaphus*). A detailed map indicating locations of all exclosure sites and riparian areas is shown in Fig. 1.

Methods

To set up Stratton as a site for long-term investigations, we established nine permanent cattle exclosures to facilitate future research on the grazing ecology of sagebrush steppe. The nine exclosures are located in three different pastures, so that grazing levels in each pasture can be controlled or manipulated for various study designs. The exclosures keep cattle out but allow for wild native ungulate grazing. Six exclosures were established in lower-elevation areas near the base of the drainage. These six sites are predominantly mountain big sagebrush. The other three exclosures are in high-elevation, windswept areas along a ridge top, with black sagebrush as the dominant shrub. In 2005, a fourth high-elevation exclosure in a predominately black sagebrush area will be established to increase sample sizes of high-elevation sites, and thus statistical power.

Data collected in 2004 is pretreatment data. We collected samples and took measurements from grazed plots and future exclosed plots (before erecting exclosure fences) to test whether grazed and exclosed plots were similar in ground cover, production of herbaceous vegetation, offtake of herbaceous vegetation, shrub size, and soil nitrogen (N) and carbon (C) content. These parameters were measured to document baseline values before experimental treatments and manipulations in the Stratton sagebrush community begin.

Offtake and Peak Standing Crop. Standing crop is the weight of plant material present in a system at any given point in time (Bonham 1989). Above-ground plant material is considered a measure of above-ground net primary production (ANP) and is estimated by harvesting standing crop when the system has attained maximum standing crop, or peak (Bonham 1989). We measured peak standing crop by clipping all vegetation within 0.25 m^2 circular plots inside 1 m^2 movable grazing exclosures that had been randomly placed at the beginning of the growing season in April-May 2004. Five cages were used per site. All graminoids, forbs, and sub-shrubs within plots were clipped and sorted into dead and live portions to measure annual peak standing crop following the methodology of Bonham (1989). Vegetation was oven-dried in a forced-air oven at 65°C for 24–48 hours and then weighed.

To measure grazing offtake by cattle and wild ungulates, vegetation within paired 0.25 m^2 plots inside and outside the five cages was clipped at peak production in 2004 (late June to early July). Cages were randomly relocated after the peak sampling to capture fall consumption and/or compensatory production after early grazing. Vegetation collected inside and outside of the grazing cages was dried at 55°C in a forced-air oven for 24 hours and then weighed. Percent consumption was calculated using the formula:

$$\% \text{ consumption} = \frac{100 * (B_i - B_o)}{B_i}$$

where B_i = dry weight of biomass inside grazing cage, and B_o = dry weight of biomass outside of the grazing cage. In 2005, additional grazing utilization cages will be established in the riparian area along Beaver Creek (three to four sites; five cages/site), and potentially in two to three nivation cirques (wet meadow areas of high snow build-up). The goal is to accurately measure grazing levels and effects by both cattle and wild ungulates, since cattle graze these wetter areas more heavily than sagebrush areas.

Groundcover. Percent cover of cactus, moss, litter, rock, bare ground, shrub, wood, cushion plant, scat, and other was determined by visually estimating percent of each of these variables in five 0.25 m2 plots at each exclosure site during peak production. We did not visually estimate percent of grass, forbs, and subshrubs. However we did calculate biomass of each of these variables using the dry weights measured for offtake and production as described above, and then converted them to percent biomass to determine ratios of grass biomass to forb biomass.

Shrubs. Number and size of shrubs were measured at each of the exclosure locations in paired grazed and future-exclosed plots. We manually measured height and canopy cross-widths of all shrubs occurring within three randomly selected 28.3 m^2 circular plots (3 m radius) to determine shrub size and density.

Soil Nitrogen and Carbon Content. To measure soil nutrients, we collected 5 soil cores at depths of 0–5 cm and 5–15 cm at each paired grazed and future-exclosed plot. Cores were taken both under and between shrubs. The five soil cores were collated into one homogenous mix, and sieved. We determined C and N content from soil samples using a LECO analyzer (Laboratory Equipment Corporation, St. Josephs, MI) by the USDA Forest Service Lab in Fort Collins, Colorado.

Statistical Analysis. Plant data is typically variable, therefore not distributed along normal frequency distributions. Each dataset was tested for normality before analysis, and nonparametric tests (Wilcoxon, Kruskal-Wallis, Kolmogrov-Smirnov) were used when necessary to analyze plant data. All statistical analyses were conducted using SAS statistical software (SAS Institute, 1988). Mean percent biomass consumed was compared between pastures and between exclosure sites for each sample period using analysis of variance (ANOVA) methods. For groundcover estimates, the five plots were averaged and means compared between paired grazed and exclosed plots using non-parametric tests. Cover and volume for shrub measurements were calculated for each shrub using SAS statistical software *V8* (SAS Institute, 1988) and means per plot determined. Comparisons of mean shrub size between paired grazed and future-exclosed plots were conducted using non-parametric tests. Comparisons of mean shrub characteristics were also made between upper and lower exclosure locations. Soil samples were analyzed by comparing paired-grazed and future-exclosed plots, and between upper versus lower exclosure locations.

Results

Exclosure sites. Statistical tests showed paired exclosed and grazed plots were not significantly different ($p > 0.05$) for all of the parameters measured (groundcover, shrub size and density, peak standing crop, and soil nutrients) prior to exclosure treatments. There were a few minor exceptions at individual exclosure sites for individual parameters, where differences were close to being significant at the $p = 0.05$ level; but overall, paired grazed and exclosed sites were very similar in vegetative composition. Pretreatment data collection is again planned for 2005 in the locations where exclosures are not yet built to re-measure any plots close to being significantly different in 2004. Based on data from 2004, we conclude any future research and experiments using long-term exclosure sites can be attributed to effects from treatments instead of pre-existing conditions.

Offtake and peak standing crop. Mean offtake at all sagebrush sites was 8% ± 19 (SE), while peak herbaceous standing crop across the study area (all sagebrush sites averaged) was 59 g/m^2 ± 14 (SE). The highest offtake was at exclosure 3, an upper-elevation site, where the grazed plot had significantly less biomass (p=0.03; Table 1) than the ungrazed plot. Lower Beaver pasture had higher grazing-use levels compared to West Beaver and Middle Beaver pastures (Table 2).

Ground cover. Percent cover of all parameters measured are shown in Table 3. Visually estimated groundcover measurements taken by BLM in 2004 along historical (long-term) transects in two drainages (Sane Creek and Beaver Creek) indicated average cover for grass as 19% and forb cover as 12% (Table 3). Biomass ratio of grass to forbs in each drainage, or exclosure location, is shown in Table 4. Mean biomass ratio of grass to forbs was approximately 4.5:1. Mean forb dry weight at Stratton was 27% of total dry weight, and average grass dry weight was 73% of total dry weight.

Shrubs. Average shrub volume was 0.511m^3 in *A.t. vaseyana* sites, and 0.025m^3 at *A. nova* sites. Average shrub cover was 0.857m^2 in *A.t. vaseyana* sites, and 0.155m^2 at *A. nova* sites, and average shrub density was 0.44 shrubs/m^2 in *A.t. vaseyana* sites, and 0.97 shrubs/m^2 at *A. nova* sites. There were no differences between grazed and exclosed plots at any of the exclosure locations for shrub volume, cover, or density. Upper-elevation exclosures had significantly higher density of shrubs than lower-elevation exclosures ($p = 0.050$), but a lower volume of shrubs ($p = 0.044$). Also, density of shrubs between grazed and exclosed plots was nearly significantly different at exclosures 1 and 2 (p= 0.063 and 0.086, respectively). We will resample shrub density again in 2005 to be sure these sites are not different in grazed versus exclosed plots.

Soil nitrogen and carbon content. No differences were found in soil N and C content in under-shrub positions or between-shrub positions at any depth (0–5 cm or 5–15 cm) between grazed versus exclosed locations ($p > 0.05$; Table 5). However, upper-elevation exclosure locations had lower N and C concentrations at 0–5 cm depth in between-shrub positions ($p = 0.028$ and 0.009, respectively; Table 5) and in under-shrub positions ($p = 0.003$ and <0.000, respectively; Table 5). No differences were detected at 5–15 cm depths in soil N and C concentration between upper- versus lower-elevation exclosures. Although no differences in soil N and C were found in grazed versus exclosed plots at individual exclosure locations, caution should be taken when comparing upper- to lower-elevation exclosures because these sites are different in soil N and C concentration at 0–5 cm depths. We intend to monitor soil N and C content after the prescribed burn (scheduled for fall 2005) as well.

Discussion

Pretreatment data indicated overall site selection for exclosures was good, and any future research using exclosure sites can attribute differences to actual treatment effects as opposed to pre-existing conditions. We plan to collect data again in 2005 to have two years of pretreatment data in the sites where exclosures are not yet built. Those sites include locations where the prescribed burn will take place; the burn needs to be conducted before exclosures are established. We caution these results are based on only one year of analysis, and there is considerable variability in plant data.

An independent review of this report suggested that different statistical analyses may be useful for this dataset. The problem is that our standard errors for peak standing crop and offtake were almost double the mean. This typically suggests a low sample-size problem, although we followed methods of Bonham (1989) and have used these methods successfully in other study areas. To address the low statistical power, we will set up the study using a BACI (Before After Control Intervention; Green 1979) design and use a Mixed Effects ANOVA for the analysis, which will increase effective *n*. We will conduct these new analyses in winter 2005-2006.

Offtake values were very low, 8% across the entire study area in sagebrush sites 2005-2006 although again, this is based on only one year of data. We believe overall offtake at Stratton was low because we measured grazing offtake away from riparian areas and nivation cirques where cattle tend to concentrate. Cattle are less likely to use sagebrush sites when areas with greater herbaceous cover and reduced shrub densities are available to them. We suspect our offtake values at Stratton are a measurement of native ungulate grazing as opposed to cattle-plus-ungulate grazing. Also, we took production and offtake measurements at peak green-up before cattle were on the site. The precipitation in 2002-2003 was low compared to the 100-year mean, and precipitation in 2004 was average to high. In 2005 we will increase plant clipping intervals to once a month to more accurately measure cattle use of the area. The highest grazing levels were found in Lower Beaver pasture, likely because the other two pastures (Upper and Middle Beaver pastures) were used only for trailing drift in 2004. We intend to measure grazing offtake at streamside locations and some nivation cirques in 2005 in order to better characterize the grazing regime and grazing offtake at Stratton.

Biomass data indicated grass biomass was almost three times that of forb biomass, which has been suggested as an important component of Greater Sage-Grouse (*Centrocercus urophasianus*) habitat (Conelly and others, 2004). We intend to measure this variable again in 2005 and take measurements after experimental burns to determine if changes in amount of forb biomass and cover versus grass may be affecting Sage-Grouse habitat quality at Stratton. In 2005 we will evaluate forb, grass, and shrub cover for Sage-Grouse and other species in the context of the Wyoming Basin Ecoregional Assessment (C. Aldridge, USGS and Natural Resources Ecology Lab, CSU, pers. commun. 2005).

We will conduct surveys at Stratton in 2005 to compare current wildlife populations to population estimates from 1968-1970. This information will give an indication of long-term changes in wildlife populations in the past 35 years, and allow us to further focus our study. In a presentation at USGS (June 8, 2005, Fort Collins Science Center), Steve Knick (Research Ecologist, USGS) reported that measuring the effects of management actions is one of the most important data needs for conserving the sagebrush biome. In particular, we need to monitor how changes in wildlife populations are occurring throughout time (S. Knick, pers. commun. 2005). We have a unique opportunity to gather relevant, current wildlife population data and compare it to historical data.

Finally, little information is available to accurately distinguish the effects of cattle grazing on vegetative characteristics across the landscape on a fine scale, pasture to pasture. We intend to more finely measure effects from cattle grazing in 2005 by increasing the number of utilization cages at Stratton. This will enable us to sample different topographic areas of vegetation types other than sagebrush, which in turn will support more refined management of the sagebrush ecosystem.

Table 1. Grazing offtake values and peak standing crop for each drainage or exclosure location at the Stratton Sagebrush Hydrology Study Area, Wyoming, 2004. Offtake and peak standing crop were measured at peak production. Peak standing crop values are in grams of herbaceous (grass + forbs) dryweight/m2. Negative offtake means grazed plots had higher average herbaceous biomass than ungrazed plots. An asterisk (*) indicates significant offtake at the p< 0.05 level (significant difference between caged versus uncaged plots).

Drainage (Exclosure No.)	Predominant sagebrush spp.	% Offtake ± SE	Peak Standing Crop (g/m^2) ± SE
Upper elevation (Excl. 1)	*A.nova*	14 ± 23	30 ± 11
Upper elevation (Excl. 2)	*A.nova*	37 ± 22	35 ± 13
Upper elevation (Excl.3)	*A.nova*	62 ± 9*	19 ± 4
Beaver Creek (Excl. 4)	*A.t. vaseyana*	-16 ± 10	55 ± 15
North Draw (Excl. 5)	*A.t. vaseyana*	-13 ± 26	76 ± 6
Middle Draw (Excl. 6)	*A.t. vaseyana*	2 ± 26	41 ± 10
South Draw (Excl. 7)	*A.t. vaseyana*	-29 ± 23	97 ± 9
Sane Creek (Excl. 8)	*A.t. vaseyana*	4 ± 17	85 ± 34
Beaver Creek (Excl. 9)	*A.t. vaseyana*	8 ± 18	93 ± 25

Table 2. Grazing offtake levels and peak standing crop for each pasture at the Stratton Sagebrush Hydrology Study Area, Wyoming, 2004. West Beaver pasture includes exclosure sites 1,8,9; Middle Beaver pasture includes exclosure sites 2,6,7; and Lower Beaver pasture includes exclosure sites 3,4,5. Peak standing crop values are in grams of herbaceous dryweight/m2.

Pasture	Predominant sagebrush spp.	% Offtake ± SE	Peak standing crop (g/m^2) ± SE
West Beaver	*A. nova*	8 ± 19	70 ± 24
Middle Beaver	*A.t. vaseyana*	3 ± 23	58 ± 11
Lower Beaver	*A.t. vaseyana*	11 ± 15	50 ± 8

Table 3. Average groundcover (± SE) for the major groundcover classes measured at each exclosure location at Stratton Sagebrush Hydrology Study Area, Wyoming, 2004. An asterisk (*) indicates grazed and exclosed plots were different at the $p< 0.05$ level.

Drainage Exclosure no.	% bareground	% rock	% shrub	% cushion plant	% litter
Upper elev. (Excl. 1)	24± 5	38± 6	3± 2	9± 3	23± 1
Upper elev. (Excl. 2)	31± 6	30± 10	11± 4	4± 2	4± 2
Upper elev. (Excl.3)	25± 4	28± 8	25± 7	7± 3	1± 1
Beaver Creek (Excl. 4)	13± 4	1± 0.5	6± 3	1± 0.9	32± 3*
North Draw (Excl. 5)	18± 7	0.2± 0.2	5± 3	0	30± 8
Middle Draw (Excl. 6)	11± 5	1± 0.9	7± 3	0.2± 0.2	37± 10
South Draw (Excl. 7)	13± 7	0	1± 0.6	0	35± 14
Sane Creek (Excl. 8)	24± 8	4± 3	5± 2	0	18± 4
Beaver Creek (Excl. 9)	12± 5	0	7± 5	0	28± 6
Sane Creek (BLM long-term transect)	26	4	12	0	28
Beaver Creek (BLM long-term transect)	15	6	24	2	37

Table 4. Biomass ratio of grass to forbs by drainage or exclosure location at the Stratton Sagebrush Hydrology Study Area, Wyoming, 2004. Ratios were calculated from herbaceous dryweight clipped at peak production.

Location	Predominant sagebrush spp.	Biomass ratio grass:forb
Drainage (Exclosure No.)		
Upper elevation (Excl. 1)	*A nova*	8:1
Upper elevation (Excl. 2)	*A.nova*	9:1
Upper elevation (Excl.3)	*A.nova*	7:1
Beaver Creek (Excl. 4)	*A.t. vaseyana*	6:1
North Draw (Excl. 5)	*A.t. vaseyana*	1:1
Middle Draw (Excl. 6)	*A.t. vaseyana*	6:1
South Draw (Excl. 7)	*A.t. vaseyana*	2:1
Sane Creek (Excl. 8)	*A.t. vaseyana*	1:1
Beaver Creek (Excl. 9)	*A.t. vaseyana*	1:1

Table 5. A comparison of upper-elevation (A. nova) exclosures versus lower-elevation (A.t. vaseyana) exclosures in mean soil nitrogen and carbon concentration at different soil depths, and in different positions (under versus between shrubs) at the Stratton Sagebrush Hydrology Study Area, Wyoming, 2004. The comparisons shown below are between A. nova sites versus A.t. vaseyana sites (not comparisons of soil position or nutrient concentration). Superscript letters indicate significant differences at the $p < 0.05$ level.

Depth; Soil sample position	% Nitrogen		% Carbon	
	A. nova sites	*A.t. vaseyana* sites	*A. nova* sites	*A.t. vaseyana* sites
0–5 cm; under-shrub	0.133^{a}	0.266^{b}	1.799^{a}	3.639^{b}
0–5 cm; between-shrub	0.144^{a}	0.240^{b}	1.743^{a}	3.113^{b}
5–15 cm; under-shrub	0.136^{c}	0.178^{c}	1.863^{c}	2.211^{c}
5–15 cm; between-shrub	0.132^{c}	0.161^{c}	1.860^{c}	1.857^{c}

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