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Author(s): Sara J. Oyler-McCance, Kenneth P. Burnham, Clait E. Braun
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INFLUENCE OF CHANGES IN SAGEBRUSH ON GUNNISON SAGE GROUSE IN SOUTHWESTERN COLORADO

SARA J. OYLER-MCCANCE,* KENNETH P. BURNHAM, AND CLAIT E. BRAUN

Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523 (SJO)
Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, CO 80523 (KPB)
Colorado Division of Wildlife, Wildlife Research Center, 317 W. Prospect Road, Fort Collins, CO 80526 (CEB)
Present address of SJO: United States Geological Survey, Midcontinent Ecological Science Center, Department of Biological Sciences, University of Denver, Denver, CO 80208
** Correspondent: sara_oyler-mccance@usgs.gov*

ABSTRACT—The decline in abundance of the newly recognized Gunnison sage grouse (*Centrocercus minimus*) in southwestern Colorado is thought to be linked to loss and fragmentation of its habitat, sagebrush (*Artemisia*) vegetation. We documented changes in sagebrush-dominated areas between the 1950s and 1990s by comparing low level aerial photographs taken in these time periods. We documented a loss of 20% or 155,673 ha of sagebrush-dominated areas in southwestern Colorado between 1958 and 1993. The amount of sagebrush-dominated area was much higher and loss rates were much lower in the Gunnison Basin. We also found that 37% of plots sampled underwent substantial fragmentation of sagebrush vegetation. If current trends of habitat loss and fragmentation continue, Gunnison sage grouse (and perhaps other sagebrush-steppe obligates) may become extinct. Protecting the remaining habitat from further loss and fragmentation is paramount to the survival of this species.

RESUMEN—La declinación en la abundancia del recientemente reconocido gallo *Centrocercus minimus* en el suroeste de Colorado (USA) se considera estar conectada a la pérdida y fragmentación del hábitat de la vegetación artemisa (*Artemisia*). Documentamos los cambios en áreas dominadas por artemisa entre 1950s y 1990s comparando fotografías aéreas a baja altura durante estos períodos. Documentamos la pérdida de 20% o 155,673 ha de áreas dominadas por artemisa en el suroeste de Colorado entre 1958 y 1993. La cantidad del área dominada por artemisa fue más alta y la taza de pérdida fue mucho menor en Gunnison Basin. También encontramos que 37% de los sitios muestreados sufrieron una fragmentación sustancial de vegetación artemisa. Si las tendencias actuales de pérdida de hábitat y fragmentación continúan, el gallo *Centrocercus minimus* (y quizás otros que viven solamente en estepa-artemisa) podrían desaparecer. Proteger el hábitat restante de más pérdida y fragmentación es primordial para la sobrevivencia de esta especie.

In Colorado, Cary (1911:246) described sagebrush-steppe vegetation as "omnipresent on the higher plains of western Colorado and also in most of the higher mountain parks up to 10,000 feet." In southwestern Colorado, sagebrush areas ranged from Debeque to Wolcott in the north, the Uncompagre Plateau in the west, Leadville to Saguache in the east, and Bayfield in the south (Cary, 1911). Rogers (1964) described the distribution of sagebrush in Colorado and reported that all sagebrush areas listed by Cary (1911) still contained some sagebrush in the early 1960s, yet due to human activities, many no longer were dominated by sagebrush. Human activities mentioned by Rogers (1964) included overgrazing, irrigation projects, and dry-farming. Braun (1995) compared the distribution of sage grouse in 1993–1994 to the range of sagebrush described by Rogers in 1964 and advocated that human-induced changes in sagebrush vegetation have negatively impacted sage grouse (*Centrocercus urophasianus*), a sagebrush-steppe obligate.

In Colorado, sage grouse have been extirpated from 12 of the 27 counties in which they occurred in the 1900s and populations in 9 of the remaining 15 counties are thought to number less than 500 breeding birds (Braun,

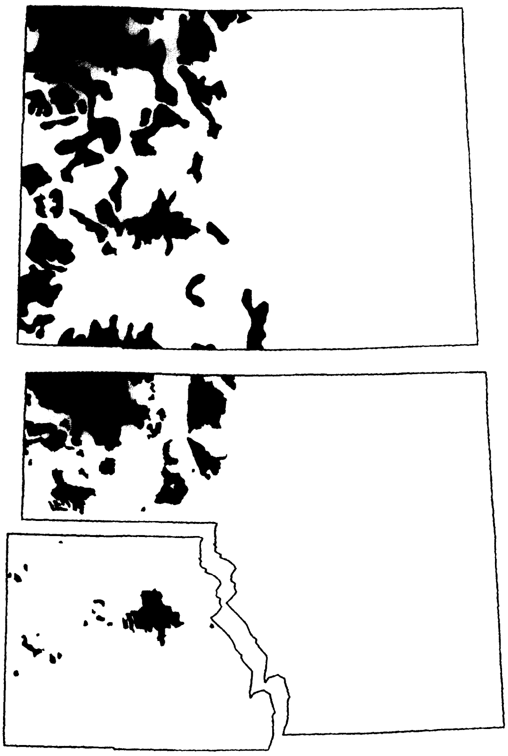

FIG. 1—Historic (top) and current (bottom) distribution of sage grouse and Gunnison sage grouse (lower left cut out) in Colorado. The area in gray represents Gunnison Basin (stratum 7).

1995). Population declines appear to be related to habitat loss (conversion of big sagebrush, *Artemisia tridentata,* into farmland or housing developments), habitat degradation (heavy livestock grazing, sagebrush removal, road and powerline development through sagebrush, and human disturbance), and habitat fragmentation (Braun, 1995). Sage grouse habitat in southwestern Colorado, the majority of the range of the newly described Gunnison sage grouse, *C. minimus* (Kahn et al., 1999; Oyler-McCance et al., 1999; Young et al., 2000), has been more severely impacted by these processes than elsewhere in Colorado (Fig. 1). Braun (1995) reported extirpation of Gunnison sage grouse from 12 of 17 counties in southwestern Colorado which once supported them, and although historic abundance is unknown, it was likely several orders of magnitude larger than the present (Young et al., 2000). This decline has caused public alarm and has resulted in a petition to list Gunnison sage grouse as a threatened or endangered species.

Sage grouse are tied to sagebrush-steppe vegetation for much of the year. In winter, sage grouse are dependent solely on sagebrush leaves (primarily big sagebrush) for food (Patterson, 1952; Wallestad et al., 1975), and they require areas dominated by sagebrush for cover (Eng and Schladweiler, 1972). In the spring, nesting occurs in thickly vegetated areas usually dominated by sagebrush (Patterson, 1952; Wallestad and Pyrah, 1974) and during brood rearing, hens with chicks are typically found in diverse habitats including areas of sagebrush (Shroeder et al., 1999). The loss of sagebrush vegetation is likely linked to the decline of Gunnison sage grouse in southwestern Colorado. Thus, we used aerial photographic analysis to document and quantify changes in sagebrush-dominated vegetation in southwestern Colorado which may be affecting the persistence of Gunnison sage grouse and perhaps other sagebrush-steppe obligates as well.

METHODS AND MATERIALS—*Plot Selection*—We identified 10 areas in southwestern Colorado which were dominated by sagebrush in the early 1960s (Rogers, 1964). Polygons were digitized around the 10 sagebrush areas in a geographic information system (GIS). We constructed a grid of sampling plots (sampling frame) covering each of the 10 polygons, with each sampling plot being a square, 4 km on a side (16 km^2/plot).

We attempted to sample 200 plots stratified across the 10 sampling polygons. The number of plots to be sampled per stratum was calculated (rounding this number to the nearest integer) such that the sampling fraction was approximately equal (ca. 9%) in each stratum. We then randomly chose plots within each stratum to achieve a stratified random sampling design (Table 1). Because we rounded the number of plots to the nearest integer, total number of plots which we intended to sample increased to 202.

Aerial Photography Acquisition and Interpretation—We attempted to obtain low level (between 1:20,000 and 1:30,000) black and white aerial photographs of each plot in the 1950s, 1970s, and 1990s. An entire plot could fit on one low level photograph (occasionally a plot was covered by a group of photographs from the same flight). Aerial photographs (either black and white film positive or color infrared) were obtained for all plots in the 1990s. Color infrared photographs were used only when black and white photographs were not available. Aerial photographs from the early years were more difficult

TABLE 1—Characteristics of strata sampled for sagebrush in southwestern Colorado.

Stratum	Area (ha)	Plots per stratum	Plots sampled per stratum
1	1,364,800	853	74
2	476,800	298	25
3	44,800	28	3
4	238,400	149	12
5	102,400	64	5
6	49,600	31	3
7	1,044,800	653	54
8	222,400	139	13
9	52,800	33	3
10	41,600	26	2

to obtain. For each plot, we developed a list of available photographs (from different years) covering that plot and chose the earliest available photographs for each plot. If there were photographs approximately midway between the earliest date and the 1990s date, we chose those photographs as well. In most cases (157 plots), only 2 photographs (an early and late photograph) could be obtained. We did obtain 3 photographs from 37 plots, which allowed us to examine rates of sagebrush change over time. We omitted 8 of the original 202 plots because there was insufficient photography covering those plots. Aerial photographs were obtained from the United States Geological Survey (USGS) Eros Data Center.

Each plot boundary was identified and traced onto a 1:24,000 7.5-minute USGS topographic quad map (or groups of maps if needed). From features on the quad map, the plot was identified on the corresponding photograph (or group of photographs). A photograph adjacent (along the same flight line) to the 1 containing the plot was identified for use on a stereoscope to visualize the plot in 3 dimensions. Acetate was then overlaid and taped to the appropriate photograph (or groups of photographs). The plot was then photo-interpreted to identify sagebrush-dominated areas. Sagebrush-dominated areas were defined to be areas in which sagebrush was the dominant (>50%) vegetation type. These areas were traced onto acetate using a Koh-i-noor Rapidograph pen with a tip to draw lines no thicker than 0.25 mm, using Rapidograph Rapidraw 3084-F ink in the drawing pen. We attempted to ground-truth 50 of the plots (25%) and were unable to gain access to 7 of the plots chosen for ground-truthing. Forty-three of the 194 plots were ground-truthed by first interpreting the photograph, then going to the area on the ground and confirming its classification as a sagebrush-dominated area.

A zoom transfer scope was used to standardize the scale and georeference the data because photographs from different years were taken at different elevations. A mylar sheet was taped to each quad map and the appropriate plot was traced onto the mylar correctly overlaying the plot traced onto the quad map. Each photograph with interpretation was placed on the zoom transfer scope and focused to the appropriate scale so that features in the photograph were lined up with features on the quad map. The interpreted sagebrush areas were traced onto the mylar sheet, removed from the quad map, scanned into a computer, and converted into a bitmap image using Adobe Photoshop. Each bitmap image was edited to correct anomalies such as closing polygons, deleting stray marks picked up by the scanner, and thinning polygon edges. The bitmap images were then imported into the GIS software ArcView (ESRI, 1996) where total area of sagebrush, number of sagebrush polygons, and area and perimeter of each sagebrush polygon were calculated.

Data Analysis—We calculated total area of sagebrush-dominated vegetation in each stratum and overall using standard methods for a stratified, simple random sampling design (Thompson, 1992; Thompson, 1997). From the estimated total area of sagebrush we estimated proportion of area that represented sagebrush-dominated vegetation in each stratum and also overall.

For each plot, we considered the most recent photograph to be the late photograph and the earliest photograph to be the early photograph. To determine the average time span between early and late photographs, we calculated average difference between years of early and late photographs. We calculated annual change in proportion of sagebrush between early and middle photographs, and between middle and late photographs for the 37 plots with 3 photographs. We then subtracted the 2 annual rates of change and tested whether this difference was different from zero.

Photographs representing each time period (early and late) were taken in different years across plots (e.g., the early time period could be represented by a photograph from mid-1940s to late-1960s). This made it difficult to compare changes in sagebrush across plots. Thus, we chose a model-based approach to standardize data to a common early and late year for comparisons across plots. We used the average early year (1958) as our standard early year and the average late year (1993) as our standard late year. Assuming that changes between time periods were monotonic, we calculated proportion of sagebrush available per plot in standard early and standard late years using a logistic function

$$\log\left(\frac{p_{early}}{1 - p_{early}}\right) = \alpha_{early} \qquad \log\left(\frac{p_{late}}{1 - p_{late}}\right) = \alpha_{late}$$

where p_{early} was proportion of area on a plot dominated by sagebrush in the early time period and p_{late} was proportion of area on a plot dominated by sagebrush in the late time period. Computing α_{early} and α_{late}, we then used the following equations

$$\alpha_{early} = a + bt_{early} \qquad \alpha_{late} = a + bt_{late}$$

to solve for $\hat{a}$ and $\hat{b}$. We then set a specific year (e.g., $t = 58$), computed $\hat{\alpha}_{58}$ using

$$\hat{\alpha}_{58} = \hat{a} + \hat{b}(58)$$

and then computed an estimated proportion of sagebrush in the given plot in year 58, $\hat{p}_{58}$, using the following equation

$$\hat{p}_{58} = \frac{1}{1 + e^{-\hat{\alpha}_{58}}}.$$

Thus, for every plot we used the logistic function and estimated proportion of area dominated by sagebrush in 1958 and in 1993. Similar standardization and projection to a given year are explained in Terrazas-Gonzalez (1997).

To obtain better estimates of within-stratum variance and confidence intervals on amount of sagebrush for strata with small sample sizes (strata 3, 4, 5, 6, 8, 9, and 10) we calculated the coefficient of variation (*CV*) of amount of sagebrush in 1958 and 1993 for each stratum. Because *CVs* tend to be stable (Eberhart, 1978) we calculated the average *CV* and used it as an estimate of *CV* for strata with small sample sizes (Carroll and Ruppert, 1988; Buckland et al., 1993). This allowed us to calculate the $z_{\alpha/2}$ multiplier for a confidence interval using 175 degrees of freedom, instead of much smaller degrees of freedom if this procedure had not been used (Tukey, 1977).

Actual confidence intervals around estimates of amount of sagebrush in 1958 and 1993 for each stratum were calculated using a log transform approach (Burnham et al., 1987). Confidence intervals around the estimate of the amount of sagebrush were calculated in a traditional way, i.e., ± 1.96 (*SE* [loss]).

To examine habitat fragmentation, we recorded number of sagebrush polygons, total area of sagebrush, and total amount of edge (total perimeter) for each plot. We then calculated the change in the square root of area to perimeter ratio (A/P) and the change in the number of polygons. Plots which had a decrease in A/P ratio and an increase in the number of polygons between time periods were thought to be affected more by habitat fragmentation, whereas plots with an increase in A/P ratio and a decrease in number of polygons were thought to be affected more by habitat loss.

RESULTS—*Habitat Loss*—Dates of early photographs ranged from 1944 to 1976 and late photographs from 1988 to 1995. The average date for early photographs was 1958 (*SD* = 6.7) and 1993 (*SD* = 1.3) for late photographs. Average number of years between early and late photographs was 35.2 (*SD* = 6.7). A difference of ca. 35 years should reflect changes in sagebrush. Only 5% of plots had less than 25 years between early and late photographs and only 9% had early photographs later than 1965. For the 37 plots with 3 photographs, difference in annual rate of change in sagebrush between early to mid time period and mid to late time period was not significantly different from zero ($t = 0.83$, $P = 0.4124$); however, sample size was likely insufficient to detect any subtle or moderate difference.

Thirty-one of the 194 plots had no sagebrush-dominated vegetation in either early or late photos. Of those plots with some amount of sagebrush in the early date, 10 plots had an increase in amount of sagebrush and 153 had a decrease. Without standardizing to a given early and late year, mean proportion of sagebrush in early years was 0.212 (*SE* = 0.016) and mean proportion in the late years was 0.173 (*SE* = 0.015). This corresponds to 772,358 ha (*SE* = 59,307) in early years and 630,274 (*SE* = 55,944) in late years, representing an 18% loss in sagebrush between early and late years.

After adjusting data based on the logistic method, the mean proportion of sagebrush available in 1958 was 0.2161 (*SE* = 0.0166) and in 1993 was 0.1734 (*SE* = 0.0154; Table 2) which converts to 786,411 ha in 1958 and 630,725 ha in 1993 with a loss of 155,673 ha (95% *CI* 124,819–186,527; Table 3). Overall, this represents a 20% loss of sagebrush-dominated area in the 35 years measured or a 0.64% annual loss rate (95% *CI* 0.49%–0.77%). Habitat loss per stratum varied (Tables 2 and 3), yet only a few strata gave reliable estimates because of small sample size. Of those strata with greater than 10 plots sampled, rate of habitat loss over the 35 year period was variable with rates as high as 50% in stratum 2 and as low as 11% in strata 7 and 8 (Table 2).

Comparison of historic and current distributions of sage grouse reveals that only 1 area in southwestern Colorado (shown in grey) seems not to have changed much (Fig. 1). This area is the Gunnison Basin which, in this study,

TABLE 2—Differences in the proportion of sagebrush in southwestern Colorado between 1958 and 1993. Mean difference in available sagebrush is the mean proportion of sagebrush available in 1958 minus the mean proportion of sagebrush available in 1993.

Stratum	Sampling fraction (sampled/ total)	Mean proportion of sagebrush available (1958)	*SE*	Mean proportion of sagebrush available (1993)	*SE*	Mean difference in available sagebrush (1958–1993)	*SE*	Rate of loss (%)	*SE*
1	74/853	0.1640	0.0237	0.1289	0.0221	0.0351	0.0052	21.40	3.19
2	25/298	0.1777	0.0385	0.0895	0.0265	0.0882	0.0241	49.63	13.54
3	3/28	0.0485	0.0458	0.0207	0.0196	0.0278	0.0263	57.32	54.11
4	12/149	0.2366	0.0737	0.1650	0.0578	0.0716	0.0221	30.26	9.33
5	5/64	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
6	3/31	0.0041	0.0039	0.0013	0.0013	0.0028	0.0027	68.29	64.70
7	54/653	0.3673	0.0414	0.3267	0.0407	0.0406	0.0053	11.05	1.44
8	13/139	0.0867	0.0401	0.0773	0.0353	0.0095	0.0052	10.84	5.99
9	3/33	0.1099	0.0447	0.0968	0.0528	0.0131	0.0109	11.92	9.95
10	2/26	0.2448	0.0065	0.1957	0.0286	0.0490	0.0220	20.06	8.99
Overall	194/2274	0.2161	0.0166	0.1734	0.0154	0.0428	0.0043	19.80	1.99

is represented by stratum 7. Because of this a priori knowledge, we combined data from all strata except stratum 7 and compared rates of habitat loss from the Gunnison Basin to all other areas. Amount of sagebrush available was much higher in the Gunnison Basin than in the rest of the areas (Tables 4 and 5). In 1958, the estimated proportion of sagebrush in the Gunnison Basin was over twice the proportion in all other areas combined (0.3673 in Gunnison versus 0.1552 in all other areas), whereas, in 1993 the proportion of sagebrush in the Gunnison Basin was almost 3 times higher than in all other areas (0.3267 in Gunnison versus 0.1116 in all other areas). The Gunnison Basin experienced a loss of only 11% compared to the combined loss of 28% elsewhere.

Habitat Fragmentation—We examined the re-

TABLE 3—Differences in the amount of sagebrush in southwestern Colorado between 1958 and 1993. Sagebrush lost is the amount of sagebrush available (ha) in 1958 minus the amount of sagebrush available (ha) in 1993.

Stratum	Area (ha)	Sagebrush available in 1958 (ha)	95% Confidence interval	Sagebrush available in 1993 (ha)	95% Confidence interval	Sagebrush lost (ha)	95% Confidence interval
1	1,364,800	223,827	168,988–296,588	175,923	126,051–245,632	47,896	33,658–62,134
2	476,800	84,732	55,735–128,974	42,669	24,193–75,352	42,065	18,441–65,688
3	44,800	2,174	701–6,920	929	258–3,451	1,245	−516–3,006
4	238,400	56,415	30,581–104,342	39,338	19,397–79,999	17,076	4,997–29,156
5	102,400	0	0–0	0	0–0	0	0–0
6	49,600	205	66–651	65	18–241	139	−58–337
7	1,044,800	383,786	308,079–478,346	341,368	267,748–435,457	42,414	31,335–53,492
8	222,400	19,289	10,703–34,872	17,180	8,699–34,043	2,109	676–3,542
9	52,800	5,801	1,861–18,436	5,111	1,409–18,952	690	−286–1,667
10	41,600	10,182	2,664–39,868	8,142	1,806–37,762	2,039	−1,494–5,573
Overall	3,638,400	786,411	667,337–905,484	630,725	520,220–741,230	155,673	124,819–186,527

TABLE 4—Differences in the proportion of sagebrush in southwestern Colorado between 1958 and 1993 when data from the Gunnison Basin (stratum 7) were compared to all other strata combined. Data were standardized to 1958 and 1993. Mean difference in available sagebrush is the proportion of sagebrush available in 1958 minus the mean proportion of sagebrush available in 1993.

Stratum	Sampling fraction (sampled/total)	Mean proportion of sagebrush available (1958)	*SE*	Mean proportion of sagebrush available (1993)	*SE*	Mean difference in available sagebrush (1958–1993)	*SE*	Rate of sagebrush loss (%)	*SE*
Gunnison Basin (7)	54/653	0.3673	0.0414	0.3267	0.0407	0.0406	0.0053	11.05	1.44
All others	140/1,621	0.1552	0.0163	0.1116	0.0141	0.0437	0.0056	28.09	3.64
Overall	194/2,274	0.2161	0.0166	0.1734	0.0154	0.0428	0.0043	19.80	1.99

lationship between change in number of polygons for each plot and change in A/P ratio (Fig. 2) and found that most of our data fell into 1 of 2 categories. Sixty-six plots (37%) had an increase in the number of polygons and a decrease in A/P ratio. This represents cases where fragmentation tends to be a stronger process than strict habitat loss. Eighty-one plots (50%) had increases in the A/P ratio and decreases in the number of polygons. In these plots, habitat loss was presumably the stronger process.

DISCUSSION—We found little difference in estimates of the proportion of habitat lost between analysis with raw and standardized data (0.039, *SE* = 0.0034 for raw data and 0.0428, *SE* = 0.0043 for standardized data). This gave us confidence that the model-based standardization using a logistic function represented the data in a reasonable way.

Although our analysis failed to find a difference in annual rate of change between early and middle time periods and between middle and late periods using a small number (37) of

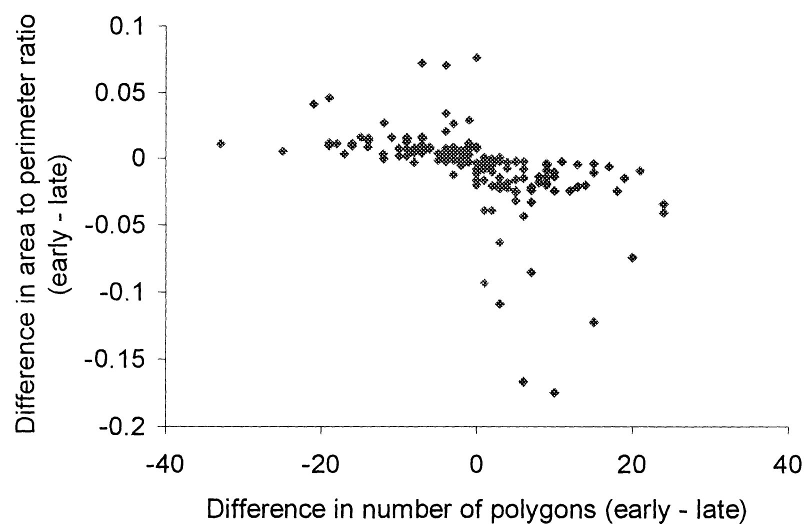

FIG. 2—Relationship between the difference in number of polygons and the area/perimeter ratio. Data in the upper left portion of the graph represent plots affected primarily by fragmentation and data in the lower right portion of the graph represent plots affected primarily by habitat loss.

TABLE 5—Differences in the amount of sagebrush in southwestern Colorado between 1958 and 1993 when data from the Gunnison Basin (stratum 7) were compared to all other strata combined. Data were standardized to 1958 and 1993. Sagebrush lost is the amount of sagebrush available (ha) in 1958 minus the amount of sagebrush available (ha) in 1993.

Stratum	Area (ha)	Sagebrush available in 1958 (ha)	95% Confidence interval	Sagebrush available in 1993 (ha)	95% Confidence interval	Sagebrush lost (ha)	95% Confidence interval
Gunnison Basin (7)	1,044,800	383,786	297,137–470,436	341,368	256,111–426,624	42,414	31,337–53,491
All others	2,593,600	402,624	318,434–486,814	289,358	216,497–362,218	113,260	84,032–142,488
Overall	3,638,400	786,411	667,337–905,484	630,725	520,220–741,230	155,673	124,819–186,527

plots, rates might differ and be higher in more recent years due to tremendous increases in human population growth in Colorado. In western Colorado, this growth was 3.1% per year between 1990 and 1996, much higher than the national average of 0.9% (Theobald, in press).

We documented a substantial loss of sagebrush throughout southwestern Colorado since 1958, but much of what was once sagebrush was already lost to other land uses before the oldest photographs in this study were taken. Rogers (1964) indicated that much of the area once abundant with sagebrush had been converted to other land uses by 1964. Overall, change in the proportion of sagebrush between 1958 and 1993 was 0.0428 (*SE* = 0.0043). This translates to a loss of 20% with 155,673 ha lost over 35 years. Average loss of sagebrush per year was 0.64% or 5,033 ha (95% *CI* 3,853–6,055).

Certain areas had much higher loss rates, especially stratum 2 (an area south of Durango and Pagosa Springs), which had an estimated loss of almost 50% (*SE* = 13.54). Sage grouse have been extirpated from this area. The Gunnison Basin had the highest proportion of existing sagebrush habitat and had one of the lowest rates of habitat loss. Our comparison of Gunnison Basin with all other data combined showed that the loss of 11% (*SE* = 1.14) in the Gunnison Basin was much lower than the loss of 28% (*SE* = 3.64) elsewhere. This is not surprising in light of Braun's (1995) comparison of historic and current sage grouse distributions (Fig. 1) in which the Gunnison Basin seems to be the only population which has not been severely reduced.

Considerable habitat fragmentation also was documented in this study. We found 66 plots in which habitat fragmentation was a strong factor in that there were more polygons in the late time period (evidence of fragmentation into smaller polygons) than in the early time period and lower A/P ratios (evidence of more perimeter per unit area). Fragmentation often results in a few remnant sagebrush patches surrounded by a matrix of land that is less suitable for sage grouse use due to development and land-use changes. It can also leave large patches of sagebrush that may contain populations of sage grouse, yet they are no longer connected to other large patches. This makes movement among patches less likely as sage grouse may be more vulnerable to predators in these instances. In this study, fragmentation was often the result of road development which is known to have a negative impact on Gunnison sage grouse (Braun, 1995; Oyler-McCance, 1999). Powerlines often parallel roads and provide perches for avian predators. Sage grouse may also be more vulnerable to flying into fences and powerlines, being hit by cars, and may be exposed to populations of nonnative predators.

Although this study documented amount of habitat loss and occurrence of habitat fragmentation, it did not measure habitat quality (with respect to sage grouse). Certainly fragmenting once continuous sagebrush habitat can influence the quality of that habitat for sage grouse by allowing invasion of nonnative plants, and creating perches and travel corridors for predators. Road development also affects quality of sage grouse habitat because it is associated with increased human activity within or near sagebrush patches. Paved roads specifically, and all human activities associated with them, have been negatively associated with Gunnison sage grouse (Oyler-McCance, 1999).

The decline in the distribution and abundance of Gunnison sage grouse is alarming (Braun, 1995). Although this study could not address habitat quality, we have documented a steady loss of sagebrush vegetation since 1958 and habitat fragmentation in a substantial number of areas. If current trends of habitat loss and fragmentation continue, Gunnison sage grouse (and perhaps other sagebrush-steppe obligates) may face extinction. Protection of these species requires proactive measures. These include assessing different management and conservation strategies including land mitigation, habitat restoration, connecting fragmented habitats, and reintroduction of sagebrush obligates into previously occupied habitats. This type of assessment is becoming more compelling with the ability to combine many different types of data (demographic, dispersal, spatial, human population) in a Geographic Information System (Oyler-McCance et al., in press) and this type of model should be used to make the best management and conservation decisions.

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