

CHANGES IN THE DISTRIBUTION AND STATUS OF SAGE-GROUSE IN UTAH

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ABSTRACT.—Sage-grouse (*Centrocercus* spp.) were abundant in all of Utah's 29 counties at the time of European settlement wherever sagebrush (*Artemisia* spp.) occurred. Greater Sage-Grouse (*C. urophasianus*) inhabited areas north and west of the Colorado River, and Gunnison Sage-Grouse (*C. minimus*) occupied suitable habitat south and east of the Colorado River. The largest Greater Sage-Grouse populations in Utah are currently restricted to suitable habitats in Box Elder, Garfield, Rich, Uintah, and Wayne Counties. A remnant breeding population of Gunnison Sage-Grouse occurs in eastern San Juan County. We stratified Greater Sage-Grouse populations (1971–2000) by counties where the 1996 to 2000 moving average for estimated spring breeding populations was >500 (GT500) or <500 (LT500). Males per lek declined in all populations from 1971 to 2000; however, there were consistently more males observed on GT500 than on LT500 leks. Juveniles per adult hen (including yearling hens) Greater Sage-Grouse in the 1973–2000 fall harvest in Box Elder, Rich, and Wayne Counties did not differ from 2.25, a ratio suggesting sustainable or increasing sage-grouse populations. Declines are attributed to loss, fragmentation, and degradation of sagebrush habitat. Sage-grouse conservation ultimately depends on management and enhancement of remaining sagebrush rangelands in Utah.

Key words: sage-grouse, sagebrush habitats, habitat loss, Utah, *Centrocercus urophasianus*, *Centrocercus minimus*, Greater Sage-Grouse, Gunnison Sage-Grouse, *Artemisia tridentata*.

Sage-grouse (*Centrocercus* spp.) are recognized for their obligate relationship with sagebrush (*Artemisia* spp.; Braun et al. 1976, Robertson 1984) and persist in Utah and 10 other states (California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Washington, and Wyoming) and 2 Canadian provinces (Alberta and Saskatchewan) where sagebrush occurs (Connelly and Braun 1997, Braun 1998). Sage-grouse have been extirpated in areas on the periphery of their core habitat including Arizona, Kansas, Nebraska, New Mexico, Oklahoma, and British Columbia (Braun 1998, Johnson and Braun 1999). Sage-grouse populations have declined throughout their remaining range at increasing rates due to habitat loss, fragmentation, and degradation (Connelly and Braun 1997, Braun 1998).

In at least 9 states and Alberta, males per lek, an index of yearly breeding populations, declined 17%–47% ($\bar{x} = 33\%$) from 1985 to 1994 from long-term averages calculated through 1984 (Connelly and Braun 1997). Utah and other states and provinces (Alberta, North Dakota, South Dakota, and Washington) with

smaller sage-grouse populations saw an overall mean decline of 37% in breeding populations from 1985 to 1994 compared to the long-term average (Connelly and Braun 1997). However, a rough estimate of breeding populations in 1998 indicated 10.6% of all sage-grouse were found in Utah (Braun 1998).

Recent work on courtship behavior (Young et al. 1994), genetics (Kahn et al. 1999, Oyler-McCance et al. 1999), morphometrics (Hupp and Braun 1991), and plumage (Young et al. 2000) led to recognition of 2 distinct species of sage-grouse, Gunnison Sage-Grouse (*C. minimus*) and Greater Sage-Grouse (*C. urophasianus*; AOU Checklist Committee 2000), also preferred or known by others as Northern Sage-Grouse (Young et al. 2000). In Utah, sage-grouse occurring south and east of the Colorado River in Grand and San Juan Counties are Gunnison Sage-Grouse, whereas sage-grouse north and west of the Colorado River are Greater Sage-Grouse (Young et al. 2000). The current Gunnison Sage-Grouse population of approximately 120–150 birds in Utah represents 3% of an estimated population of 4000–5000 in

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Utah and Colorado (USDI Fish and Wildlife Service 2000, Young et al. 2000). In December 2000, Gunnison Sage-Grouse were added to the list of candidate species for listing under the Endangered Species Act of 1973 (USDI Fish and Wildlife Service 2000).

An analysis of the distribution and status of sage-grouse in Utah is needed to assist in the conservation and management of populations and essential habitats within the state. Similar syntheses have been completed for sage-grouse in Colorado (Braun 1995), Oregon (Willis et al. 1993), and Washington (Schroeder et al. 2000). Our paper clarifies what is known about the original and current distribution of sage-grouse in Utah, provides historical and current status information about the species, and discusses causes of sage-grouse declines and the need for conservation in relation to habitat conditions. In our synthesis we (1) reviewed literature, examined museum specimens, and performed geographical analyses to evaluate the current and historical distribution of sage-grouse in Utah; and (2) analyzed population data to evaluate trends (1971–2000) in sage-grouse abundance and productivity in the state.

METHODS

Personnel from the U.S. Bureau of Land Management (BLM), U.S. Forest Service (USFS), U.S. Natural Resources Conservation Service, and Utah Division of Wildlife Resources (UDWR) met in 4 interagency regional meetings in 1998 and 1999 and compiled available data, retrieved from each of the respective agency's files, on sage-grouse populations and habitat. New spatial data were combined with existing spatial data and are maintained in UDWR's Geographic Information System (GIS) database. Sage-grouse population data were combined into a database maintained by UDWR. We incorporated these data sets in our analyses.

Historical and Current Distribution

We constructed a list of sage-grouse collected in Utah by examining ornithological collections at Brigham Young University (BYU) in Provo, College of Eastern Utah in Price, and University of Utah (UU) in Salt Lake City. C.E. Braun (personal communication, July 2002) provided survey information for the Weber

State University (WSU) ornithological collection in Ogden and accession records from the major North American museums. We derived the current distribution of sage-grouse in Utah from information and maps provided by BLM, UDWR, and USFS biologists. This information was digitized into a GIS (ArcView™ Version 3.2, Environmental Systems Research Institute, Redlands, CA).

Historical distribution of sage-grouse in Utah was mapped using the current distribution map as the initial data layer and then adding areas of historical distribution as supporting evidence was found. Historical observations of sage-grouse from early research in Utah, early scientific explorations, and UDWR Job Progress Reports were all used to identify historical distribution of sage-grouse. Literature was reviewed to obtain estimates of the original distribution of big sagebrush (*A. tridentata*) and other species of sagebrush (low sagebrush [*A. arbuscula*], black sagebrush [*A. nova*], and threetip sagebrush [*A. tripartita*]; Beetle 1960, Küchler 1964, Foster 1968, Bailey 1976, McArthur and Ott 1996). We used the Utah GAP vegetation coverage to add areas of historical sagebrush distribution to the initial sage-grouse distribution layer if these areas were not already identified (Edwards et al. 1995). Additional cover types from Utah GAP were added to the historical map if topographical relief was moderate and if sagebrush was an important component of the plant community (e.g., Gambel's oak [*Quercus gambelii*]-sagebrush, salt desert scrub-sagebrush, and pinyon [*Pinus* spp.]-juniper [*Juniperus* spp.]-sagebrush) to account for the diversity of habitats within the sagebrush biome (Miller and Eddleman 2001).

Current Status

Data collected since 1959 by UDWR on Greater Sage-Grouse were stratified by counties according to whether the breeding population of sage-grouse in each county exhibited a 5-year (1996–2000) moving average of greater than 500 (GT500; persistent) or less than 500 (LT500; at risk of extirpation; Braun 1995). Gunnison Sage-Grouse were considered separately from Greater Sage-Grouse. Counties represent discrete geographical populations from which data have been recorded since 1959. Maximum number of males observed from the highest of 3 lek counts was the sample statistic

used to estimate breeding population size relative to each lek (Beck and Braun 1980) with the assumptions that (1) 75% of all males were observed during the peak count, and (2) the male-to-female ratio was 1:2.0 (C.E. Braun, personal communication, January 2002).

We define a lek as a traditional strutting ground where sage-grouse congregate to display and breed in spring. Furthermore, UDWR considers historical leks to be those where displaying male sage-grouse have not been observed for 5 or more years, and inactive leks to be those where displaying males have not been observed for up to 3 years. Active leks comprise those where males were observed during at least 1 of the 2 previous years.

A Greater Sage-Grouse lek was established in an isolated area of north central San Juan County by birds translocated in 1976 (Reese and Connelly 1997). These grouse were not considered in any analyses as they were artificially placed within historical Gunnison Sage-Grouse habitat, and no males have been observed on this lek since 1996. Initial collection of data sets began at different dates for different populations. However, by spring 1971, lek counts represented most sage-grouse populations in the state. Statistical testing thus represents data collected from 1971 to 2000. Statistical significance was set at $\alpha \leq 0.05$.

LEK COUNTS.—All lek count data were collected by UDWR biologists. Biologists were directed to count male sage-grouse on leks according to the following protocol: (1) observe each lek a minimum of 3 times annually at approximate weekly intervals between 20 March and 1 May, and (2) record the maximum number of male sage-grouse observed at each instance of lek observation. Biologists were also instructed to conduct lek counts (1) following the peak of breeding (mid-March to early April), the apex of male lek attendance (Jenni and Hartzler 1978, Emmons and Braun 1984); (2) within half an hour before and after sunrise, to coincide with the period of greatest daily lek attendance (Jenni and Hartzler 1978); and (3) when weather conditions permitted optimal visibility and did not hinder grouse activity (Autenrieth et al. 1982). We assume biologists followed the protocol above to collect lek count data. Yearly maxima from each lek were used to evaluate trends in male lek attendance over time (Jenni and Hartzler 1978, Autenrieth et al. 1982).

Maximum males per lek were averaged by year for GT500, LT500, and Gunnison Sage-Grouse populations. Correlations were performed between males per lek in all populations (GT500, LT500, and Gunnison Sage-Grouse) and year to evaluate the relationship of lek counts over time (PROC CORR; SAS Institute, Inc. 2000). A generalized ANOVA using maximum likelihood with a time series error structure was used to test the hypothesis that males observed per lek were higher in GT500 populations than in LT500 populations from 1971 to 2000 (PROC MIXED; SAS Institute, Inc. 2000).

PRODUCTIVITY.—Wings from Greater Sage-Grouse harvested from 1973 to 2000 in GT500 counties were used to calculate annual juvenile-to-adult female (including yearlings) ratios to evaluate productivity (Eng 1955, Autenrieth et al. 1982). We estimated mean juvenile-to-adult female ratios with a 2-stage approach using a stratified cluster sample. Counties were strata (stage 1) and wing samples were clusters (stage 2) within these counties (Scheaffer et al. 1996). Box Elder, Rich, and Wayne Counties were selected as strata due to missing data from Garfield and Uintah Counties; sufficient data for comparing LT500 populations were not available after 1981. Wing ratios were weighted by mean proportion of total males counted on leks in these 3 counties over this 28-year period to make each county's contribution to the estimated mean ratio proportional to population size. Recommendations by Connelly et al. (2000a) suggest a ratio of 2.25 juveniles per adult hen (including yearling hens) should indicate a stable to increasing population. We used a 1-sample *t* test (PROC TTEST; SAS Institute, Inc. 2000) to test the null hypothesis that mean juveniles per adult hen did not differ from 2.25 from 1973 to 2000.

We calculated lambda ($\lambda [N_{t+1}/N_t]$), the finite rate of increase (Akçakaya et al. 1999), for lek counts in Box Elder, Rich, and Wayne Counties from 1973 to 2000. We correlated these λ 's with lagged juvenile-to-adult (including yearling hens) hen ratios (e.g., mean wing ratio from 1973 correlated with λ from 1974/1973) to evaluate the relationship of change in annual growth rates with productivity from the previous fall (PROC CORR; SAS Institute, Inc. 2000).

RESULTS

Historical Distribution

Franciscan missionaries Silvestre Vélez de Escalante and Francisco Atanasio Domínguez and their exploring party visiting Utah Valley in September 1776 were the first Europeans to describe sage-grouse in Utah. They reported that "wild hens" (i.e., sage-grouse and/or Columbian Sharp-tailed Grouse [*Tympanuchus phasianellus columbianus*]) around Utah Lake were abundant and used by Native Americans as a source of food (Auerbach 1943). Early naturalists visiting Utah observed that sage-grouse were abundant, even near settlements until at least the 1870s (Allen 1872, Henshaw 1875, Hayward et al. 1976). Henshaw (1875:437) reported:

The sage hen is very numerous throughout Utah; its predilection, as its name implies, being for the open, barren plains of *Artemisia*; and whenever this plant exists in abundance, whether on the extensive stretches of open plain on the lowlands, entirely barren but for the growth of this shrub, or in the valleys high up among the mountains, this bird will not be looked for in vain.

His observations suggest sage-grouse originally occurred in all of Utah's 29 counties coincident with sagebrush communities (Fig. 1). Sage-grouse declined near settlements concurrent with early agricultural development (Allen 1872, Christensen and Johnson 1964). Allen (1872) noted the magnitude of agricultural development in the Salt Lake Valley in autumn 1871 while "ornithologizing" between Ogden and Salt Lake City (i.e., Davis, Salt Lake, and Weber Counties). His party collected sage- and sharp-tailed grouse specimens, but observed only about a dozen of each species, even though they were informed of their former abundance there.

Sage-grouse apparently were abundant where suitable habitat existed throughout Utah until at least the early 1900s (Hayward et al. 1976) and were distributed in many areas across the state until at least the 1950s (Lords 1951, Aldrich and Duvall 1955). From 1949 to at least 1954, the *Utah Fish and Game Bulletin* published a series of articles entitled "Stories of Old Timers." These articles featured interviews with settlers who lived in Utah during the mid- to late 1800s and early 1900s. These

pioneers recalled substantial populations of sage-grouse on the benches of Utah County, in Heber and Strawberry Valleys in Wasatch County, Summit County, the benches of Cache County, and Box Elder County (e.g., Utah Fish and Game 1953). Sage-grouse were abundant near Sevier Lake in Millard County in the mid-1800s (Christensen and Johnson 1964). Pine Valley in north central Washington County was populated by sage-grouse until at least the mid-1900s (Behle 1943, Aldrich and Duvall 1955, Jense and Trevort 1973).

We found 108 Greater Sage-Grouse museum specimens and/or egg sets representing Beaver, Box Elder, Cache, Carbon, Daggett, Duchesne, Grand, Salt Lake, Tooele, Uintah, Utah, and Wasatch Counties. No specimens of Gunnison Sage-Grouse were found. Of note were 1 specimen collected in Salt Lake County in December 1892 (American Museum of Natural History, No. 353711) and 1 egg set (Royal Ontario Museum, Toronto, No. 8385) collected in Salt Lake County in May 1902. The earliest collected specimens at BYU, dated 5 July 1926, were 2 from the Strawberry Reservoir area of Wasatch County. In the UU collection, the earliest records were of 2 sage-grouse collected on 5 September 1932 in the Lynn Canyon area of Box Elder County. The single specimen at WSU (No. 00060) was collected 1 August 1898 in the vicinity of Heber City, Wasatch County. Early records of sage-grouse from Utah County include egg sets collected from West Mountain (1893 and 1913) and other locations in 1898, 1901, and 1927 in the collection of the Western Foundation of Vertebrate Zoology. We are uncertain of the exact collection locale (most likely in eastern Tooele County) for a specimen (University of Missouri-Columbia, No. 04001335) reportedly taken 40.2 km (25 mi) west of Salt Lake City on 26 September 1966.

McArthur and Ott (1996) reported total potential cover of big sagebrush and its close relatives in Utah following Küchler's (1964) map (vegetation types 38 and 55) was 35,315 km² and following Bailey's (1976) map (ecoregions 3131, 3133, and A3142) was 17,489 km². These areas are respectively equivalent to 16.05% and 7.95% of the total area of Utah (McArthur and Ott 1996). However, West (1983a, 1983b) indicated that in Utah the total cover of sagebrush semidesert was 15.1% (27,000 km²) and sagebrush-steppe was 2.4% (11,100 km²). Thus, prior to settlement, big sagebrush communities,

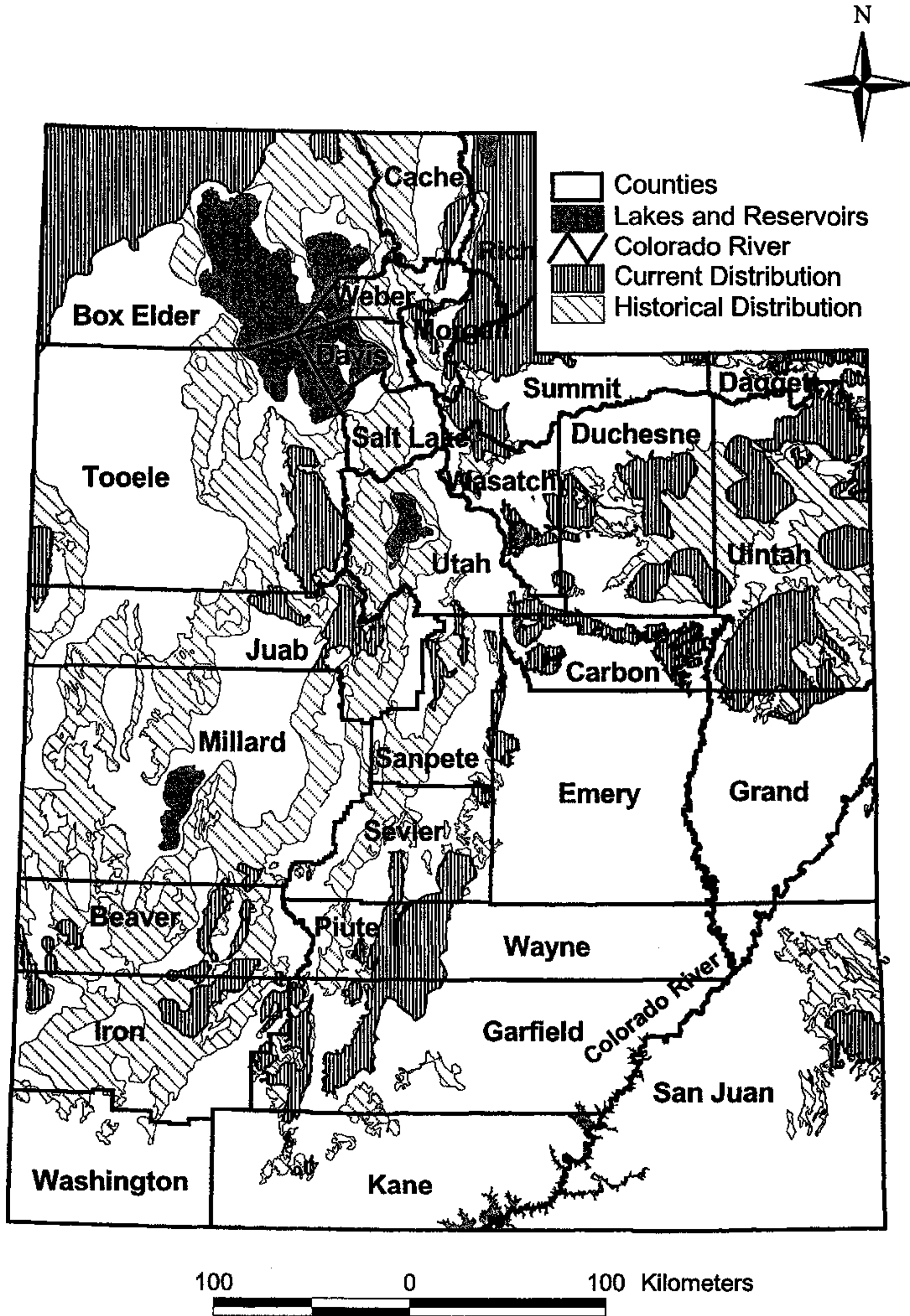


Fig. 1. Current and historical distribution of sage-grouse in Utah. Gunnison Sage-Grouse are found south and east of the Colorado River and Greater Sage-Grouse inhabit areas north and west of the Colorado River.

the core of sage-grouse habitat, probably covered about 8–17.5% of Utah.

Current Distribution

Our geographical analyses indicate Utah consists of 219,838 km², of which historically 72,995 km², or 33.2%, may have been used by sage-grouse (Greater Sage-Grouse 32.2% [70,696 km²] and Gunnison Sage-Grouse 1.0% [2299 km²]; Fig. 1). Our analyses also indicate 29,821 km² (13.6%) of Utah currently provides habitat for sage-grouse (Fig. 1). Greater Sage-Grouse inhabit 29,208 km² (97.9%) and Gunnison Sage-Grouse 613 km² (2.1%) of this area. The current distribution of sage-grouse represents 40.9% of the historical distribution of sage-grouse in Utah. Thus, Greater and Gunnison Sage-Grouse may currently occupy 41.3% and 26.7%, respectively, of their potential historical distribution. The largest Greater Sage-Grouse populations in Utah are presently restricted to Blue and Diamond Mountains in Uintah County, Parker Mountain (mainly in Wayne County), Rich County, western Box Elder County, and western Garfield County (Fig. 1).

Lek Counts

Three hundred twenty sage-grouse leks are known in Utah, of which 162 (51%) were actively used from 1998 to 2000. Thirty-two (10%) were inactive and 124 (39%) were historical and not active from 1996 to 2000. Lek counts by county were initiated in Box Elder and Rich in 1959; Summit in 1962; Cache in 1966; Garfield, Piute, Sevier, Uintah, and Wayne in 1967; Beaver, Carbon, Emery, Iron, San Juan, and Tooele in 1968; Morgan in 1969; Daggett, Duchesne, and Wasatch in 1970; Juab and Sanpete in 1971; Millard in 1975; Utah in 1976; and Kane in 1983. Lek sampling intensity (leks and total males subsequently counted) generally increased from 1959 to 2000 (Table 1). The highest number of leks counted since 1959 was 167 in 1988 and 2000. The lowest number of leks counted was 13 in 1959 and 1961 (Table 1). One hundred sixty-seven leks were counted throughout Utah in spring 2000, with 57 Gunnison and 3459 Greater Sage-Grouse males observed (Table 1).

Breeding populations in Box Elder, Garfield, Rich, Uintah, and Wayne Counties were estimated at greater than 500 breeding Greater

Sage-Grouse from 1996 to 2000. Counties with less than an estimated 500 breeding Greater Sage-Grouse from 1996 to 2000 included Beaver, Cache, Carbon, Daggett, Duchesne, Emery, Iron, Juab, Kane, Millard, Morgan, Piute, Sanpete, Sevier, Summit, Tooele, Utah, and Wasatch. Sage-grouse no longer occur in Davis, Salt Lake, and Washington Counties. Sage-grouse were last observed on leks in 1994 in Emery County, 1988 in Millard County, 1983 in Sanpete County, and 1977 in Utah County, and may now be extirpated in these counties. Only 1 male sage-grouse has been observed (spring 2000) on a lek in Summit County since 1995.

The only sage-grouse observed on a lek in Sevier County since 1978 were birds translocated from 1987 to 1990 that formed a new lek (Reese and Connelly 1997). Leks are not known in eastern Weber County, and birds harvested there through the 1970s most likely attended adjacent leks in Cache and Morgan Counties. Only historical leks are known in northern Grand County; thus sage-grouse harvested there by hunters through the early 1990s displayed on leks in nearby Uintah County. In addition, a small population of Gunnison Sage-Grouse that breeds in Mesa County, Colorado, frequents Grand County along the east central state boundary.

Males per lek declined in all populations from 1971 to 2000 (GT500, $r = -0.38$, $P = 0.0397$; LT500, $r = -0.78$, $P < 0.0001$; Gunnison Sage-Grouse, $r = -0.74$, $P < 0.0001$; Table 1, Fig. 2). Highest number of males per GT500 lek was observed in 1979 (30.7 , $s_{\bar{x}} = 4.9$, $n = 62$) and lowest was observed in 1996 (12.7 , $s_{\bar{x}} = 1.6$, $n = 88$). In LT500 populations, highest number of males per lek was observed in 1972 (20.6 , $s_{\bar{x}} = 2.9$, $n = 41$) and lowest was observed in 1996 (6.2 , $s_{\bar{x}} = 1.3$, $n = 46$; Fig. 2). Long-term (1971–2000) average males observed on leks in GT500 populations was 20.4 ($s_{\bar{x}} = 0.8$); 12.5 ($s_{\bar{x}} = 0.7$) in LT500 populations; and 13.8 ($s_{\bar{x}} = 1.1$) for Gunnison Sage-Grouse in San Juan County. Number of males per lek in GT500 populations was higher than in LT500 populations from 1971 to 2000 ($F_{1,29} = 91.95$, $P < 0.0001$).

Productivity

Long-term (1973–2000) mean juveniles per adult hen (including yearlings) analyzed from wings from hunter-harvested sage-grouse in

TABLE 1. Number of leks counted and high counts of male sage-grouse on leks in Utah, 1959–2000. Greater Sage-Grouse stratified by counties as LT500 = less than 500, or GT500 = greater than 500 for the 1996–2000 average breeding population.

Year	Gunnison Sage-Grouse		Greater Sage-Grouse				Total count	
	Leks	Males	LT 500		GT 500		Leks	Males
			Leks	Males	Leks	Males		
1959	N/A	N/A	N/A	N/A	13	442	13	442
1960	N/A	N/A	N/A	N/A	14	522	14	522
1961	N/A	N/A	N/A	N/A	13	623	13	623
1962	N/A	N/A	4	129	10	343	14	472
1963	N/A	N/A	3	21	15	534	18	555
1964	N/A	N/A	4	51	11	245	15	296
1965	N/A	N/A	4	33	12	194	16	227
1966	N/A	N/A	5	57	13	236	18	293
1967	N/A	N/A	7	116	34	853	41	969
1968	2	8	16	151	35	929	53	1088
1969	3	42	25	562	46	1765	74	2369
1970	6	123	27	668	58	1811	91	2602
1971	6	156	41	809	63	1389	110	2354
1972	6	175	41	846	71	1507	118	2528
1973	6	105	32	498	64	1238	102	1841
1974	6	137	55	887	76	1431	137	2455
1975	6	115	47	881	64	1262	117	2258
1976	6	98	61	1096	58	1302	125	2496
1977	5	117	67	1107	75	1831	147	3055
1978	5	96	60	908	57	1674	122	2678
1979	4	67	48	793	62	1902	114	2762
1980	5	41	37	535	63	1354	105	1930
1981	4	63	69	721	82	1717	155	2501
1982	4	47	49	590	50	1362	103	1999
1983	4	59	55	667	62	1178 ^a	121	1904
1984	3	51	19	181	31	547 ^a	53	779
1985	3	32	34	371	84	1252	121	1655
1986	3	18	46	594	56	1054	105	1666
1987	3	21	50	475	61	1294	114	1790
1988	3	21	55	573	109	1944	167	2538
1989	3	30	51	707	85	1962	139	2699
1990	3	28	58	598	86	2151	147	2777
1991	3	24	50	594	76	1725	129	2343
1992	3	36	43	426	64	1258	110	1720
1993	3	38	26	200	58	971	87	1209
1994	3	35	33	213	74	1087	110	1335
1995	3	38	20	147	61	811	84	996
1996	3	28	46	285	88	1117	137	1430
1997	3	25	44	344	103	1356	150	1725
1998	3	32	49	386	93	1688	145	2106
1999	5	46	52	688	105	2135	162	2869
2000	5	57	62	887	100	2572	167	3516

^aAerial counts were conducted for grouse on all leks in Wayne County in 1983 and 1984.

Box Elder, Rich, and Wayne Counties was 2.4 ($s_{\bar{x}} = 0.2$; Fig. 3). Mean juveniles per adult hen in fall harvests in these counties from 1973 to 2000 did not differ from 2.25 ($t_{27} = 0.73$, $P = 0.4740$). Wings received from hunters declined in Box Elder (-53%) and Wayne (-23%) Counties and increased in Rich County (+46%), while the ratio of juveniles to adult hens in-

creased in Box Elder County (+53.3%) but decreased in Rich (-17.3%) and Wayne (-12.8%) Counties in the period from 1973–1986 to 1987–2000 (Table 2). We detected a moderate relationship between ratio of juveniles per adult hen the previous fall and growth rates (λ) for males per lek the following spring ($r = 0.36$, $n = 27$, $P = 0.0682$).

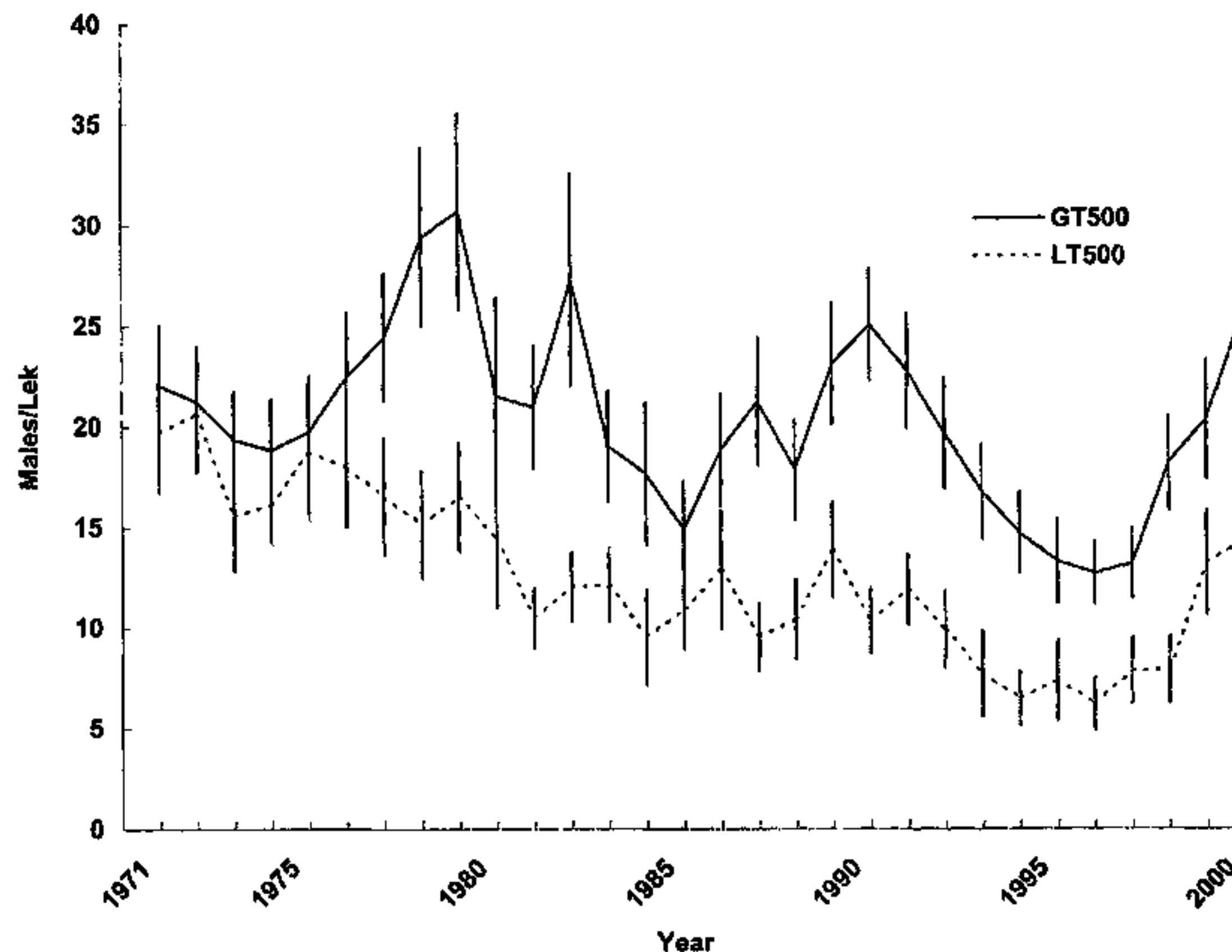


Fig. 2. Males per lek ($\bar{x} \pm s_{\bar{x}}$), GT500 and LT500 Greater Sage-Grouse county populations, Utah, 1971–2000.

DISCUSSION

Historical and Current Distribution

The accuracy of our GIS analyses on historical and current distribution of sage-grouse in Utah is unknown. However, our analyses indicate a decline in potential habitat of at least 60% and 70% for Greater and Gunnison Sage-Grouse populations, respectively. In addition, 49% of known leks throughout Utah are no longer used by sage-grouse. Lek counts represent only a 42-year period (1959–2000); consequently, the number of historical leks is not clear. Therefore, we argue that the decline in sage-grouse distribution in Utah since historical times is far greater than 50% as suggested by the Utah Division of Wildlife Resources (1997).

Throughout the range of sage-grouse, habitat loss, fragmentation, and degradation have reduced the quantity and quality of habitat, especially for nesting and early brood-rearing (Connelly and Braun 1997). Reduction in quantity and quality of sage-grouse habitat can occur over a short time period (Enyeart 1956, Swenson et al. 1987) or can occur gradually (Welch et al. 1990). Loss, fragmentation, and degradation of sage-grouse habitat has occurred

across Utah as an incremental process. Establishment of settlements along sagebrush foothills and in valleys and subsequent ploughing of arable areas led to initial habitat loss (Allen 1872, Christensen and Johnson 1964). Settlement was closely followed by livestock grazing, which degraded surrounding habitats by inducing changes in sagebrush community composition (Cottam and Stewart 1940, Cottam 1947).

Livestock overgrazing, agricultural activities, and fire disturbances promoted establishment of annual weeds, in particular cheatgrass (*Bromus tectorum*; Stewart and Hull 1949, Young and Allen 1997). Cheatgrass was first collected in Utah in 1894 (Warg 1938), and expansion since then has led to increased fire frequencies in xeric (often Wyoming big sagebrush [*A. t. wyomingensis*]) communities (Bunting et al. 1987), which subsequently limits recovery of brood-rearing habitats in dry sagebrush types (Fisher et al. 1996). Following World War II, additional sagebrush was lost and/or degraded as ranges were converted through mechanical and chemical means to increase grass forage (usually crested wheatgrass [*Agropyron cristatum*]) for livestock (Enyeart 1956, Beck and Mitchell 2000). Fire suppression and overgrazing have facilitated invasion of sagebrush

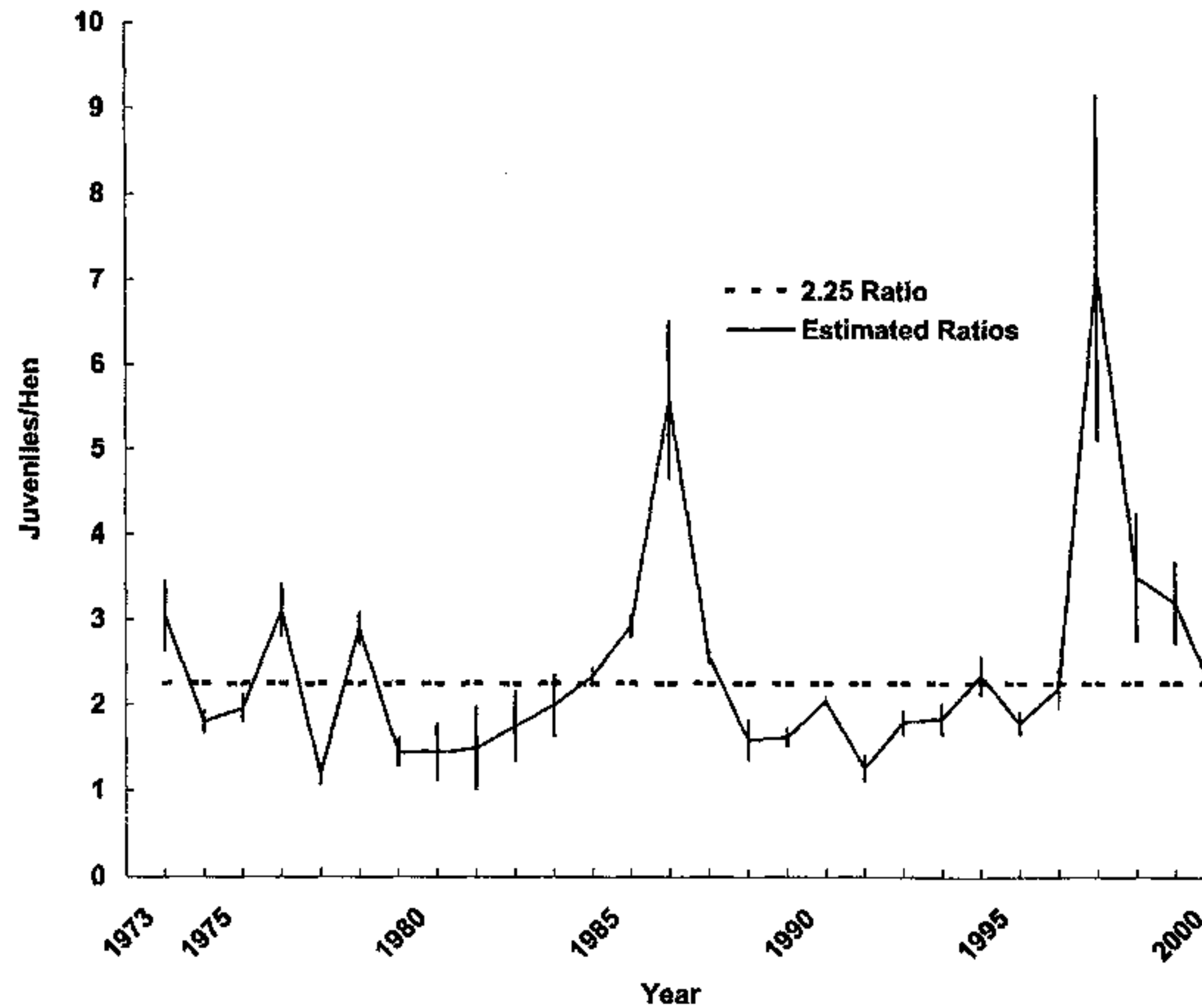


Fig. 3. Estimated ratios ($\bar{x} \pm s_x$) of juveniles per adult hen (including yearling hens) Greater Sage-Grouse in the fall harvest from Box Elder, Rich, and Wayne Counties, Utah, 1973–2000. Estimated ratios compared to a ratio of 2.25 juveniles per hen, a level suggesting stable to increasing populations (Connelly et al. 2000a).

by pinyon-juniper woodlands (Miller et al. 1994), which has led to additional loss of sage-grouse habitat (Commons et al. 1999). Additional losses, fragmentation, and degradation have arisen from surface mining and energy developments, roads, powerlines, fences, reservoirs, and housing developments (Braun 1987, 1998).

Sage-grouse in Strawberry Valley provide a particularly compelling history of habitat conditions that have induced declines in a Utah sage-grouse population. During the mid-1930s, an estimated population of 3000–4000 grouse was present during spring, summer, and fall on what was then called Strawberry Valley Federal Refuge (Rasmussen and Griner 1938). Within 15 years sage-grouse in Strawberry Valley (excluding the area below the dam) had declined to 1500 birds (Lords 1951). The sage-grouse population in Strawberry Valley further decreased to an estimated 160–185 birds by 1989 (Welch et al. 1990). Loss and degradation of sage-grouse habitat in Strawberry Valley has resulted from overgrazing, chemical control of sagebrush, reservoir enlargement, summer homes, roads, and campgrounds (Ras-

mussen and Griner 1938, Welch et al. 1990). Although much work has been done to rehabilitate remaining big sagebrush habitat in Strawberry Valley, additional factors including establishment of sod-forming grasses (e.g., smooth brome [*Bromus inermis*]) in sagebrush understories and colonization of an exotic predator (red fox [*Vulpes vulpes*]) may preclude this population from recovering (Bunnell 2000).

Long-term trends (1971–2000) in Utah indicate marked declines in all breeding populations, particularly in Gunnison and smaller Greater Sage-Grouse populations. Careful management will be required to keep all populations from further reductions. Protection and enhancement of all known sage-grouse use areas and populations must be a top priority to insure sage-grouse remain an important component of Utah sagebrush ecosystems.

Lek Counts

Increased emphasis by UDWR to understand population dynamics of sage-grouse throughout the state led to enhanced lek sampling efforts over time. Lek count results since

TABLE 2. Trend in wing receipts and juveniles per adult hen (including yearling hens) ratios from hunter-harvested Greater Sage-Grouse in Box Elder, Rich, and Wayne Counties, Utah, 1973–2000. Wing receipts and juveniles per hen are $\bar{x} \pm s_{\bar{x}}$ for each 14-year period.

	Box Elder	Rich	Wayne
1973–1986			
Wing receipts	333 \pm 47	98 \pm 20	268 \pm 16
Juveniles per hen	1.9 \pm 0.2	2.7 \pm 0.5	2.5 \pm 0.2
1987–2000			
Wing receipts	158 \pm 28	143 \pm 31	207 \pm 24
Juveniles per hen	2.9 \pm 0.8	2.2 \pm 0.2	2.2 \pm 0.2
Percent change ^a			
Wing receipts	-53	+46	-23
Juveniles per hen	+53.3	-17.3	-12.8

^aDifferences (%) between 1973–1986 and 1987–2000 means.

1996 may thus be artifactual, and higher counts during this time period, at least in part, reflect intensified sampling efforts. Problems with early (through the 1960s) lek counts include inadequate equipment, personnel commitment, and a lack of understanding of sage-grouse biology (Braun 1998). We presented the most precise lek sampling data as information from 1971 and later, when leks in most areas were being counted. However, the accuracy of lek counts is still poorly understood. The relationship between lek counts and total population size has not been documented, even though substantial effort has been expended on refining methods to obtain lek counts (Beck and Braun 1980). Although lek counts have been used to estimate prairie grouse populations, they are meant to serve as indices of population trends over time (Applegate 2000). Nevertheless, indices of density, such as lek counts, provide measures of relative population size and are useful to track year-to-year changes in single populations as well as to compare the size or density of 2 populations (Caughley and Sinclair 1994:215). Despite the faults of lek count methodologies, they provide the best index to breeding populations over time (Connelly and Braun 1997, Connelly et al. 2000a).

Productivity

Our results suggest juvenile-to-adult hen ratios may have been sufficient to promote sustainable or even increasing populations of sage-grouse from 1971 to 2000 (Connelly et al. 2000a). Females and juveniles are typically harvested disproportionately to males in late-summer hunts because broods tend to congre-

gate near moist areas at this time of year (Braun 1998, Connelly et al. 2000b). Consequently, since the late 1990s sage-grouse hunting seasons in Utah have been shortened, bag limits reduced (1 bird daily and possession limit of 2 daily bag limits since 1997), and opening dates held later in September (3rd Saturday since 1997; 2nd Saturday before 1997) to conserve breeding females. It is possible that, prior to these new regulations, ratios exceeding 2.25 juveniles per adult hen (including yearling hens) in the fall harvest may reflect disproportionate harvests of hens and young near wet areas in early September. In addition, the overwinter survival rate of juvenile and yearling sage-grouse across Utah is unknown. Low overwinter survival of these key segments of the population could also be contributing to the decline of sage-grouse populations in Utah.

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LITERATURE CITED

- AKÇAKAYA, H.R., M.A. BURGMAN, AND L.R. GINZBURG. 1999. Applied population ecology: principles and computer exercises using RAMAS® EcoLab 2.0. 2nd edition. Applied Biomathematics, Setauket, New York.
- ALDRICH, J.W., AND A.J. DUVALL. 1955. Distribution of American gallinaceous game birds. USDI Fish and Wildlife Service Circular 34:1-30.
- ALLEN, J.A. 1872. Ornithological notes from the West. Part III: Notes on the birds of the Great Salt Lake Valley. American Naturalist 6:394-404.
- AOU CHECKLIST COMMITTEE. 2000. Forty-second supplement to the American Ornithologists' Union checklist of North American birds. Auk 117:847-858.
- APPLEGATE, R.D. 2000. In my opinion: use and misuse of prairie chicken lek surveys. Wildlife Society Bulletin 28:457-463.
- AUERBACH, H.S. 1943. Father Escalante's journal 1776-77 newly translated with related documents and original maps. Utah Historical Quarterly 11:1-142.
- AUTENRIETH, R.E., W.A. MOLINI, AND C.E. BRAUN. 1982. Sage grouse management practices. Western States Sage Grouse Committee Technical Bulletin 1. Idaho Department of Fish and Game, Twin Falls. 42 pp.
- BAILEY, R.G. 1976. Ecoregions of the United States. Map, scale = 1:7,500,000. United States Department of Agriculture, Forest Service, Washington, DC.
- BECK, J.L., AND D.L. MITCHELL. 2000. Influences of livestock grazing on sage grouse habitat. Wildlife Society Bulletin 28:993-1002.
- BECK, T.D.I., AND C.E. BRAUN. 1980. The strutting ground count: variation, traditionalism, management needs. Proceedings of the Western Association of Fish and Wildlife Agencies 60:558-566.
- BEETLE, A.A. 1960. A study of sagebrush—the section *Tridentatae* of *Artemisia*. University of Wyoming Agricultural Experiment Station Bulletin 368. University of Wyoming, Laramie. 83 pp.
- BEHLE, W.H. 1943. Birds of Pine Valley Mountain region, southwestern Utah. Bulletin of the University of Utah, Biological Series 34(2):1-85.
- BRAUN, C.E. 1987. Current issues in sage grouse management. Proceedings of the Western Association of State Fish and Wildlife Agencies 67:134-144.
- _____. 1995. Distribution and status of sage grouse in Colorado. Prairie Naturalist 27:1-9.
- _____. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139-156.
- BRAUN, C.E., M.F. BAKER, R.L. ENG, J.W. GASHWILER, AND M.H. SCHROEDER. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88: 165-171.
- BUNNELL, K.D. 2000. Ecological factors limiting sage grouse recovery and expansion in Strawberry Valley, Utah. Master's thesis, Brigham Young University, Provo, UT.
- BUNTING, S.C., B.M. KILGORE, AND C.L. BUSHEY. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. General Technical Report INT-231, United States Department of Agriculture, Forest Service, Ogden, UT. 33 pp.
- CAUGHLEY, G., AND A.R.E. SINCLAIR. 1994. Wildlife ecology and management. Blackwell Science, Cambridge, MA. 334 pp.
- CHRISTENSEN, E.M., AND H.B. JOHNSON. 1964. Presettlement vegetation and vegetational change in three valleys in central Utah. Brigham Young University Science Bulletin, Biological Series 4(4):1-16.
- COMMONS, M.L., R.K. BAYDACK, AND C.E. BRAUN. 1999. Sage grouse response to pinyon-juniper management. Pages 238-239 in S.B. Monson and R. Stevens, compilers, Proceedings—ecology and management of pinyon-juniper communities within the Interior West. Proceedings RMRS-P-9, USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.
- CONNELLY, J.W., AND C.E. BRAUN. 1997. Long-term changes in sage grouse (*Centrocercus urophasianus*) populations in western North America. Wildlife Biology 3:229-234.
- CONNELLY, J.W., M.A. SCHROEDER, A.R. SANDS, AND C.E. BRAUN. 2000a. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967-985.
- CONNELLY, J.W., A.D. APA, R.B. SMITH, AND K.P. REESE. 2000b. Effects of predation and hunting on adult sage grouse *Centrocercus urophasianus* in Idaho. Wildlife Biology 6:227-232.
- COTTAM, W.P. 1947. Is Utah Sahara bound? University of Utah Bulletin 37(11):1-32.
- COTTAM, W.P., AND G. STEWART. 1940. Plant succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862. Journal of Forestry 38:613-626.
- EDWARDS, T.C., JR., C.G. HOMER, S.D. BASSETT, A. FALCONER, R.D. RAMSEY, AND D.W. WIGHT. 1995. Utah GAP analysis: an environmental analysis system. Final Project Report 95-1. Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan. 38 pp.
- EMMONS, S.R., AND C.E. BRAUN. 1984. Lek attendance of male sage grouse. Journal of Wildlife Management 48:1023-1028.
- ENG, R.L. 1955. A method for obtaining sage grouse age and sex ratios from wings. Journal of Wildlife Management 19:267-272.
- ENYEART, G. 1956. Responses of sage grouse to grass reseeding in the Pines area, Garfield County, Utah. Master's thesis, Utah State Agricultural College, Logan.
- FISHER, R.A., K.P. REESE, AND J.W. CONNELLY. 1996. An investigation on fire effects within xeric sage grouse brood habitat. Journal of Range Management 49: 194-198.
- FOSTER, R.H. 1968. Distribution of the major plant communities in Utah. Doctoral dissertation, Brigham Young University, Provo, UT.
- HAYWARD, C.L., C. COTTAM, A.M. WOODBURY, AND H.F. FROST. 1976. Birds of Utah. Great Basin Naturalist Memoirs 1. Brigham Young University, Provo, UT. 229 pp.
- HENSHAW, H.W. 1875. Report upon ornithological collections made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona, during the years 1871, 1872, 1873, and 1874, in report upon geographical and geological explorations and surveys west of the one hundredth meridian. Volume 5, Zoology, chapter 3, pages 133-507. U.S. Government Printing Office, Washington, DC.

- HUPP, J.W., AND C.E. BRAUN. 1991. Geographic variation among sage grouse in Colorado. *Wilson Bulletin* 103:255-261.
- JENNI, D.A., AND J.E. HARTZLER. 1978. Attendance at a sage grouse lek: implications for spring censuses. *Journal of Wildlife Management* 42:46-52.
- JENSE, G., AND P. TREVORT. 1973. Sage grouse inventory, southern region, job progress report. Utah Division of Wildlife Resources, Pitmann-Robertson Project W-65-R, Salt Lake City, UT. 19 pp.
- JOHNSON, K.H., AND C.E. BRAUN. 1999. Viability and conservation of an exploited sage grouse population. *Conservation Biology* 13:77-84.
- KAHN, N.W., C.E. BRAUN, J.R. YOUNG, S. WOOD, D.R. MATA, AND T.W. QUINN. 1999. Molecular analysis of genetic variation among large- and small-bodied sage grouse using mitochondrial control-region sequences. *Auk* 116:819-824.
- KÜCHLER, A.W. 1964. Manual to accompany the map, potential natural vegetation of the conterminous United States. Special Publication 36, American Geographical Society, New York. 166 pages and 1:3,168,000 scale map.
- LORDS, J.L. 1951. Distribution, ecology and population dynamics of the sage grouse in Utah. Master's thesis, University of Utah, Salt Lake City.
- MCCARTHUR, E.D., AND J.E. OTT. 1996. Potential natural vegetation in the 17 conterminous western United States. Pages 16-28 in J.R. Barrow, E.D. McArthur, R.E. Sosebee, and R.J. Tausch, compilers, Proceedings of the symposium on shrubland ecosystem dynamics in a changing environment. General Technical Report INT-GTR-338, United States Department of Agriculture, Forest Service, Ogden, UT.
- MILLER, R.F., AND L.L. EDDLEMAN. 2001. Spatial and temporal changes of sage grouse habitat in the sagebrush biome. Oregon State University Agricultural Experiment Station, Technical Bulletin 151. 35 pp.
- MILLER, R.F., T.J. SVEJCAR, AND N.E. WEST. 1994. Implications of livestock grazing in the Intermountain sagebrush region: plant composition. Pages 101-146 in M. Vavra, W.A. Laycock, and R.D. Pieper, editors, Ecological implications of livestock herbivory in the West. Society for Range Management, Denver, CO.
- OYLER-MCCANCE, S.J., N.W. KAHN, K.P. BURNHAM, C.E. BRAUN, AND T.W. QUINN. 1999. A population genetic comparison of large- and small-bodied sage grouse in Colorado using microsatellite and mitochondrial DNA markers. *Molecular Ecology* 8:1457-1466.
- RASMUSSEN, D.I., AND L.A. GRINER. 1938. Life history and management studies of the sage grouse in Utah, with special reference to nesting and feeding habits. *Transactions of the North American Wildlife Conference* 3:852-864.
- REESE, K.P., AND J.W. CONNELLY. 1997. Translocations of sage grouse *Centrocercus urophasianus* in North America. *Wildlife Biology* 3:235-241.
- ROBERSON, J.A. 1984. Sage grouse-sagebrush relationships: a review. Pages 157-167 in E.D. McArthur and B.L. Welch, compilers, Proceedings of the symposium on the biology of *Artemisia* and *Chrysothamnus*. General Technical Report INT-200, United States Department of Agriculture, Forest Service, Ogden, UT.
- SAS INSTITUTE, INC. 2000. SAS/STAT user's guide. Release 8.1. SAS Institute, Inc., Cary, NC.
- SCHEAFFER, R.L., W. MENDENHALL III, AND R.L. OTT. 1996. Elementary survey sampling. 5th edition. Duxbury Press, Boston, MA.
- SCHROEDER, M.A., D.W. HAYS, M.F. LIVINGSTON, L.E. STREAM, J.E. JACOBSON, AND D.J. PIERCE. 2000. Changes in the distribution and abundance of sage grouse in Washington. *Northwestern Naturalist* 81:104-112.
- STEWART, G., AND A.C. HULL. 1949. Cheatgrass (*Bromus tectorum* L.)—an ecological intruder in southern Idaho. *Ecology* 30:58-74.
- SWENSON, J.E., C.A. SIMMONS, AND C.D. EUSTACE. 1987. Decrease of sage grouse *Centrocercus urophasianus* after ploughing sagebrush steppe. *Biological Conservation* 41:125-132.
- USDI FISH AND WILDLIFE SERVICE. 2000. Endangered and threatened wildlife and plants; notice of designation of the Gunnison Sage-Grouse as a candidate species. *Federal Register* 65(250):82310-82312.
- UTAH DIVISION OF WILDLIFE RESOURCES. 1997. Utah upland game. Publication 63-12, Utah Division of Wildlife Resources, Salt Lake City. 54 pp.
- UTAH FISH AND GAME. 1953. Stories of old timers. *Utah Fish and Game Bulletin*, June:5-6.
- WARG, S.A. 1938. Life history and economic studies on *Bromus tectorum*. Master's thesis, State University of Montana, Missoula.
- WELCH, B.L., F.J. WAGSTAFF, AND R.L. WILLIAMS. 1990. Sage grouse status and recovery plan for Strawberry Valley, Utah. Research Paper INT-RP-430, United States Department of Agriculture, Forest Service, Ogden, UT. 10 pp.
- WEST, N.E. 1983a. Great Basin-Colorado Plateau sagebrush semi-desert. Pages 331-349 in N.E. West, editor, Temperate deserts and semi-deserts. Volume 5. Ecosystems of the world. Elsevier Scientific Publishing Company, Amsterdam.
- _____. 1983b. Western Intermountain sagebrush steppe. Pages 351-374 in N.E. West, editor, Temperate deserts and semi-deserts. Volume 5. Ecosystems of the world. Elsevier Scientific Publishing Company, Amsterdam.
- WILLIS, M.J., G.P. KEISTER, JR., D.A. IMMELL, D.M. JONES, R.M. POWELL, AND K.R. DURBIN. 1993. Sage grouse in Oregon. P. R. Project W-87-R-8, sub-285. Wildlife Research Report 15, Oregon Department of Fish and Wildlife, Portland. 69 pp.
- YOUNG, J.A., AND E.L. ALLEN. 1997. Cheatgrass and range science: 1930-1950. *Journal of Range Management* 50:530-535.
- YOUNG, J.R., C.E. BRAUN, S.J. OYLER-MCCANCE, J.W. HUPP, AND T.W. QUINN. 2000. A new species of sage-grouse (Phasianidae: *Centrocercus*) from southwestern Colorado. *Wilson Bulletin* 112:445-453.
- YOUNG, J.R., J.W. HUPP, H.W. BRADBURY, AND C.E. BRAUN. 1994. Phenotypic divergence of secondary sexual traits among sage grouse, *Centrocercus urophasianus*, populations. *Animal Behaviour* 47:1353-1362.

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