Impacts of extensive chemical control of sand sagebrush on breeding birds

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ABSTRACT: Breeding bird responses to an extensive sand sagebrush control program in southwest Kansas were evaluated for 5 years after treatment. Surveys conducted in adjacent treated and untreated sand sagebrush prairie pastures indicated that extreme variations in bird diversity and abundance on the treated pasture were associated with sharp annual changes in the herbaceous community during the first 3 years after chemical treatment. A decline in bird diversity and abundance was observed in the fourth and fifth years after treatment, following structural decay of the dead sagebrush. Bobwhites were no longer present on the treated pasture in the fourth year but remained abundant on the control pasture. If avian diversity and abundance is to be maintained, extensive solid-block treatments of sand sagebrush should be avoided.

CHEMICAL treatment of sagebrush (*Artemisia spp.*) range to increase livestock forage production has been widely practiced, but relatively few studies have reported the impacts of such treatments on breeding birds. Wildlife responses are best documented for species with obligate dependency on sagebrush, such as sage grouse (*Centrocercus urophasianus*) (*6, 15, 22*) and Brewer's sparrows (*Spizella brewer*) (*3, 19*). Most reported research on sagebrush control and birds was conducted in the intermountain West and for only 1 to 3 years following chemical treatment. As Wiens and Rotenberry (*23*) have suggested, such short-term studies may yield incomplete or misleading results.

Sand sagebrush (*Artemisia fillifolia*) is found extensively on sandy soils of the high plains from South Dakota to New Mexico. Wildlife responses to chemical treatment of sand sagebrush rangeland have been virtually undocumented except for limited studies directed at lesser prairie chickens (*Tympanuchus pallidicinctus*) (*8, 12*).

In 1978, chemical control of sand sagebrush was initiated on the Cimarron National Grassland in extreme southwestern Kansas. About 60% of the 43,000 ha (107,000 acres) administered by the U.S. Forest Service was dominated by sand sagebrush. Although a wildlife management plan for the area, completed by the U.S. Forest Service and the Kansas Fish and Game Commission in 1979, specified that treatment of sand sagebrush in strips and small blocks would create a desirable mosaic of vegetation communities, about 4,000 ha (10,000 acres) of sand sagebrush were treated annually from 1979 through 1984 in large contiguous blocks. This unexpected deviation from the wildlife management plan prompted this study but also prevented pretreatment assessment. Our objective was to evaluate the effects of this extensive chemical control of sand sagebrush by monitoring relative levels of breeding bird populations a minimum of 5 years following treatment.

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Study area and methods

We selected for study an untreated pasture of sand sagebrush prairie similar to that described by Küchler (*14*) and Hullett and associates (*11*) and an adjacent treated pasture known to have had similar vegetational composition prior to 2, 4-D (2, 4-dichlorophenoxyacetic acid) spraying. Except for about 100 ha (250 acres) of peripheral buffer areas, West College Pasture (903 ha) (2,230 acres) had been treated aerially with 1.7 kg/ha (1.5 pounds/acre) of 2, 4-D during June 1979. East College Pasture (846 ha) (2,090 acres) served as an untreated control until it was similarly treated in June 1984.

The two study pastures were part of a three-unit allotment managed under deferred rotation grazing. Each unit was grazed by 300 to 400 cows with calves during 2 months of each year: May-June, July-August, or September-October. Between 1979 and 1984, grazing pressure on the control unit was slightly heavier (0.71-0.95 AUM/ha, 1.75-2.35 AUM/acre) than on the 2, 4-D treated unit (0.66-0.88 AUM/ha, 1.63-2.17 AUM/acre). Cattle typically were rotated from the control to the treated pasture except in years when the control pasture was grazed during September and October.

Ten listening stations were marked in each pasture at 320-m (0.2-mile) intervals along a line roughly parallel to and 1.2 km (0.75 mile) south of the riparian zone of the Cimarron River. The first station in each pasture was 320 m (0.2 mile) from the common boundary between the study pastures.

Sagebrush kill was measured by counting dead and live sagebrush plants intercepted by a roughly linear vehicle track left between the listening stations in both pastures in 1980. This was repeated in the treated pasture in 1982. Other vegetational differences between years and transects were assessed visually and documented photographically.

Breeding bird surveys were conducted between May 30 and June 18 from 1980 through 1984. We began the surveys simultaneously at station 1 in each pasture 30 minutes before sunrise on dry mornings. Observers recorded the position and species of all birds heard singing during 2-minute listening intervals at each station. Only surveys in which the wind remained less than 20 km/h (12 miles/hour) during the 60 to 70 minutes needed to listen and walk between the stations were considered acceptable. Each observer completed two surveys, one on each transect, in all years except 1981, when surveys were completed on only 1 day with acceptably low winds.

Crows of ring-necked pheasants (*Phasianus colchicus*) and the gobbling of lesser prairie chickens were recorded but were excluded from the analysis because the substantial distance at which these sounds were detectable made it difficult to determine audibily if these birds' positions were within the study pastures. Although western kingbirds (*Tyrannus verticalis*), eastern kingbirds (*T. tyrannus*), and northern orioles (*Icterus galbula*) were observed foraging in the study pastures, they were considered residents of the nearby riparian zone and were not included in this analysis.

Daily observations at each station constituted the basic sampling units. A series of nonparametric tests was run using Statistical Analysis System (*16*) NPAR1WAY procedures. Results of these tests were examined for agreement, and reported probabilities represent the weakest values obtained. Differences in Shannon-Weaver diversity indices (H') between transects were tested following Zar (*25*).

Results

Vegetative structure and composition in the control pasture appeared stable during the study. Only 3% of the 1,000 sagebrush plants sampled in this pasture in 1980 were dead. In 1984, however, unexpected aerial spraying of the control pasture with 2, 4-D only two days before our surveys curled the green growth on the sagebrush. Our observations do not suggest that this treatment jeopardized the legitimacy of East College Pasture as a study control in 1984. For example, nest success of sagebrush obligate Brewer's sparrows was not affected during the year of chemical treatment in Wyoming (19). The 1984 treatment of the control pasture did, however, negate planned extension of the study.

In contrast, the treatment pasture exhibited substantial vegetative changes during the five years following the 1979 treatment. Sagebrush control was nearly total. In 1980, 94% of the 1,210 sand sagebrush plants sampled were dead, and 99% of 905 plants were dead when sampling was repeated in 1982.

In June of 1980, residual grass cover, particularly sand dropseed (*Sporobolus cryptandrus*), was clearly more abundant on the 2, 4-D-treated pasture than on the adjacent control pasture. Dead sagebrush plants retained their smallest twigs and were structurally equivalent to the live sagebrush in the control pasture. Green foliage on live sagebrush in the treatment pasture was restricted to sprouting at the base of the plant and provided little additional cover.

In 1981, dead sagebrush plants showed little structural change. Prairie sunflower (*Helianthus petiolarus*) and lambsquarter (*Chenopodium album*) dominated the vegetation in the treatment pasture at the time of the surveys. These species had obtained heights exceeding 0.5 m (1.6 feet) and virtually obscured the dead sagebrush. In sharp contrast, sunflowers were much less abundant and less mature in the control pasture. Lambsquarter was proportionally even less evident in the control pasture.

Excet for the near absence of live sagebrush, plant composition in the treatment pasture appeared similar to the control from 1982 through 1984. Structural decay of the dead sagebrush, however, became increasingly apparent in the treatment pasture. About one-third of the sagebrush plants had lost essentially all of their small twigs by 1982, leaving only the main stems and larger branches. Small twigs were absent from all dead sagebrush plants by 1983, and the stems and larger branches were broken on most plants. By 1984, virtually all vertical structure previously provided by the dead sagebrush was gone.

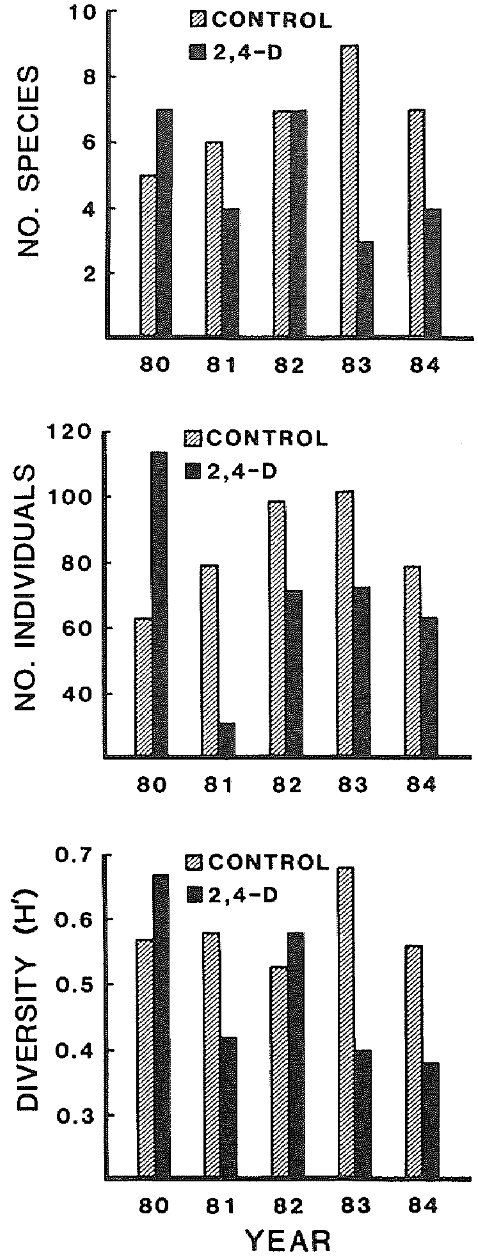

Figure 1. Number of species and individuals and diversity of breeding birds observed in control and 2, 4-D-treated sand sagebrush prairie pastures.

The mean number of singing birds observed per station on the treated area was 1.8 times greater ($P < 0.0001$) than was found on the control in 1980 (Table 1). The 2, 4-D-treated pasture also yielded seven species and a greater ($P < 0.05$) Shannon-Weaver diversity index of 0.67, compared to respective values of 5 and 0.57 from the control pasture (Figure 1).

Avian populations decreased sharply on the 2, 4-D-treated pasture in 1981 (Table 1), two years after spraying. The mean number of birds per station in the control pasture was 2.5 times greater ($P < 0.001$) than was observed in the treated pasture. Ubiquitous western meadowlarks (*Sturnella neglecta*) accounted for 65% of the observations in the treated pasture. Avian diversity was less ($P < 0.05$) on the treated pasture (0.42) than on the control (0.58), most notably because grasshopper sparrows (*Ammodramus savannarum*) and Cassin's sparrows (*Aimophila cassinii*), both common in 1980, had virtually abandoned the treated pasture.

Except for a greater ($P < 0.001$) number of Cassin's sparrows on the control pasture (Table 1), avian species composition and abundance were similar on both pastures in 1982 (Figure 1). Diversity indexes did not differ between the control (0.53) and the treatment (0.58) pastures.

Only three species of birds were observed singing in the 2, 4-D-treated pasture, com-

Table 1. Mean number of singing birds heard per station in control and 2, 4-D-treated sand sagebrush prairie pastures.*

	Mean Number of Singing Birds by Year and Treatment									
	1980		*1981*		*1982*		*1983*		*1984*	
Species	*Control*	*2, 4-D*	*Control*	*2, 4-D*	*Control*	*2, 4-D*	*Control*	*2, 4-D*	*Control*	*2, 4-D*
Brewer's sparrow (*Spizella breweri*)							0.15		0.10	
Cassin's sparrow (*Aimophila cassinii*)	2.15	3.60††	3.40†††	0.10	5.30†††	2.45	4.50†	3.20	4.10†	3.40
Field sparrow (*Spizella pusilla*)		0.20								
Grasshopper sparrow (*Ammodramus savannarum*)	0.30	1.60†††	0.30		0.30	0.05	0.20			0.20†
Lark sparrow (*Chondestes grammacus*)					0.10	0.10	0.30†		0.40†	
Western meadowlark (*Sturnella neglecta*)	2.25	3.30††	2.20	2.00	2.55	2.25	2.50	3.45††	2.30	2.60
Eastern meadowlark (*Sturnella magna*)			0.10							
Mockingbird (*Mimus polyglottos*)									0.45†††	
Mourning dove (*Zenaida macroura*)	0.15	0.45	0.30	0.30	0.10	0.25	0.75	0.60	0.15	0.10
Bobwhite (*Colinus virginianus*)	1.45	2.15	1.60†	0.60	1.35	2.00	1.30†††			
Scaled quail (*Callipepla squamata*)					0.15	0.05	0.10			
Unknown		0.05					0.35††		0.40††	
All species	6.30	11.35†††	7.90†††	3.10	9.85†††	7.15	10.15††	7.25	7.90†††	6.30

*Blanks indicate no observations of the species.
†Mean is statistcally greater than the paired mean or, when the paired value is blank, the mean is statistically greater than 0 at $P<0.05$ (†), $P<0.01$ (††), or $P<0.001$ (†††).

pared to nine on the untreated control in 1983. Species diversity was significantly greater ($P < 0.001$) on the control area (0.68) than on the treated pasture (0.40), and the mean number of birds observed singing per station was also higher ($P < 0.01$) in the control pasture (Table 1).

Although Brewer's sparrows had not been recorded previously, two were observed on the control pasture in 1983. These birds may have been remnants of a population that had existed on a site about 15 km (9 miles) away, which was treated with 2, 4-D in 1982. Declines of 54% and 67% have been reported in Brewer's sparrow numbers one year after total kills of big sagebrush (*A. tridentata*) (*3, 19*).

The most apparent difference between the study pastures in 1983 was the absence of bobwhites (*Colinus virginianus*) on the 2, 4-D-treated pasture, whereas the control maintained a substantial population, comparable to that of previous years. The importance of sand sagebrush to bobwhites in this region is well documented (*18, 20*).

Following an extremely severe winter, which included the coldest December ever recorded (*21*), no bobwhites were observed in either study pasture in 1984. The few surviving bobwhites occupied portions of the riparian zone along the Cimarron River. Despite the absence of bobwhites and scaled quail (*Callipepla squamata*), seven species of birds were recorded within the control pasture in 1984, compared to only four species in the treatment pasture. More individuals ($P < 0.001$) were heard at control stations (Table 1), and species diversity (Figure 1) was also greater ($P < 0.02$) on the control pasture (0.56) than on the 2, 4-D-treated pasture (0.38).

Discussion

Substantial differences in breeding bird indexes between the control and 2, 4-D-treated pastures occurred in 1980 and 1981 simultaneous with obvious changes in the vegetation on the treated pasture. The species most closely associated with grass abundance, including grasshopper sparrows and Cassin's sparrows (*2*), were present in greater numbers on the treated pasture in 1980. This probably was the result of the greater relative availability of residual grassy cover in the treated pasture, produced by a lack of post-spray grazing and by reduced forb and shurb competition in 1979. Conversely, these bird species were virtually absent in 1981, when the treated pasture was dominated by annual forbs. These variations in vegetation and dependent birds appeared to be relatively short-term responses to the 2, 4-D treatment.

Although time constraints did not permit significant vegetation sampling, we observed no visually apparent differences in herbaceous plant composition between the control and 2, 4-D-treated pastures in 1982, 1983, or 1984. The only obvious vegetation changes involved the structural deterioration of dead sand sagebrush plants in the treated pasture. In 1982, when most dead sagebrush plants were still structually intact, we detected little difference in breeding bird communities on the control and treated pastures. Breeding bird diversity, however, declined sharply on the treated pasture by 1983, when advanced structural decadence of the dead sagebrush was first observed. Diversity remained low in 1984. We believe this relatively poor diversity and abundance of birds is attributable substantially to the loss of habitat structure that the sagebrush had provided. If this is correct, the impoverished bird community observed in 1983 and 1984 represents a lasting effect, which will persist until sand sagebrush significantly recovers on the treated pasture.

Our data suggest a delayed negative response, which was not apparent in the bird community until four years after West College pasture was treated with 2, 4-D. Similar time lags have been suggested from experimental sagebrush manipulation (*24*) and from evaluation of larger scale treatment of sagebrush range (*23*). Such time lags may produce misleading results in short-term studies (*23*).

It has been suggested that breeding site loyalty (philopatry) in birds may account for reported time lags (*24*). In our study, however, the delayed declines in bird abundance and diversity on the treatment pasture appeared to be associated with changes in habitat structure. For example, the overwhelming dominance of annual forbs in 1981 resulted in virtual abandonment of the treatment pasture by Cassin's sparrows, but this species reoccupied this pasture at near normal levels the subsequent year. Similarly, bobwhites remained in abundance on the treatment pasture as long as the profile of the dead sagebrush remained intact but abruptly abandoned it once the sagebrush structure became decadent. Structually intact, but dead, brush also has been reported to provide an adequate habitat profile two years after chemical treatment in the Siera Nevada of California (*1*).

Our study pastures were not situated in areas most used by scaled quail and were too small to evaluate lesser prairie chicken use. But, the extensive treatment of sand sagebrush on the Cimarron National Grassland was probably detrimental to both species. Strong preference of sand sagebrush habitat by scaled quail has been reported in southeastern Colorado and the Oklahoma Panhandle (*10, 17*). Similarly, the importance of sand sagebrush to lesser prairie chickens is well known (*5, 8, 9, 12, 13*). Management for sand sagebrush cover has been advocated to benefit these birds (*5*), and abandonment of traditional mating sites was reported following an extensive kill of sand sagebrush in Texas (*12*). Partial control of sand sagebrush, however, showed no short-term effect on lesser prairie chicken numbers in northwestern Oklahoma (*8*).

Conclusions and implications

Following short-term fluctuations in the first three years after treatment, avian abundance and diversity on the 2, 4-D-treated pasture exhibited a decline in the fourth and fifth years. This decline occurred simultaneously with structural decadence of 2, 4-D-treated sand sagebrush and was particularly marked by abandonment of the treated pasture by bobwhites in the fourth year. If other treated pastures were similarly abandoned by bobwhites and suspected negative impacts on scaled quail and lesser prairie chickens were realized, recreational hunting quality on the Cimarron National Grassland was diminished.

A similar loss of recreational potential may have resulted from the reduction in avian diversity. Bird watchers are not only attracted to variety and abundance in an avian community but also seek observation of species uncommon in their experience. The avian community that ultimately resulted after the sagebrush treatment was less diverse, was less abundant, and contained only the more ubiquitous species, compared to that of the untreated pasture.

Ample evidence suggests that sagebrush control need not be incompatible with wildlife benefits. Whether concerned with nongame birds (*3, 24*) or game birds (*8, 22*), studies that evaluated partial (<50%) or well interspersed sagebrush kills detected little negative impact. In contrast, extensive sagebrush kills have proven highly detrimental to birds in this and other studies (*12, 15, 19*).

If sagebrush control is to be compatible with bird abundance and diversity, it should be implemented to create a patchy environment by treating irregular strips or small blocks (*4, 7*). Incomplete kill is desirable, even on treated areas. Erosion control measures, such as treating strips at right angles to prevailing winds (*4*), would have been appropriate for the sandy soils on much of the Cimarron National Grassland.

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Intrepretive variability of four soil map units for forest management

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ABSTRACT: The purity of soil map units depends upon the distribution and kinds of soil taxa, landform configuration, and geology of the region to be inventoried. Soil map units may be dominant in one soil taxon (consociation) or may be composed of more than one taxon (complex or association). Published soil maps show the various soil taxa and other components of the landscape. Variability is inherent in soil map units. Conveying this variability to users is essential to the proper use of soil surveys. This study was conducted to determine the purity of four soil mapping units (two consociations and two complexes) and their relationship to selected soil-woodland interpretive ratings. A stratified random transect sampling scheme was used to collect field data. Shannon's measure of entropy was used to express the variability within the map units. Results show the percentage and kinds of inclusions present. Because most inclusions found have similar interpretations to the named soil, the map units still differentiate areas having similar woodland interpretive ratings.

THE federal government and other agencies began mapping soils on a regular basis in 1899. Today, mapping continues to be an important activity of the Soil Conservation Service, Forest Service, and other agencies involved in the National Cooperative Soil Survey program. One of the long standing goals of the soil survey has been to provide information for users on the behavior of soils when they are used for a given purpose.

Evidence of soil variability is well documented (*1*, *13*). The main thrust of variability studies has centered on taxonomic variability within soil map units, spurred by the adoption of soil taxonomy (*11*). Few studies have concentrated on the variability of interpretations within soil map units. Miller (*6*) indicated that users need and desire more information on soil variability in soil survey reports, as evidenced in areas undergoing urbanization. Edmonds and Lentner (*3*) suggested means of improving transfer of information on map unit composition to users.

With the advent of geographic information systems (GIS), a new phase of data presentation is evolving for soil surveys. In the future, users may be presented with site-, soil-, and use-specific information rather than an entire soil survey manuscript, which may not alone provide users enough information on variability within map units.

The supporting information in a soil survey report provides an indication to astute readers of the inherent variability in soils. Burrough (*2*) indicates that thematic maps convey to users an unrealistic degree of homogeneity. Thus, supporting information must be provided to users concerning survey techniques, sampling and statistical methods, qualitative and quantitative descriptions of soil variability for their areas of interest, and implications for intended use.

Our study was undertaken to (a) assess the variability of interpretations within soil map units for forest land management and (b) suggest a means of presenting variability information to users. Because forestry is a major industry in the Upper Peninsula of Michigan, the research concentrated on woodland interpretations.

Methods

The study area, Houghton County in the Upper Peninsula of Michigan, is on the Canadian Shield and is underlain predominantly by Precambrian igneous and metamorphic rocks. Relief ranges from a high of 457 m (1,500 feet) to a low of 183 m (600 feet) at the Lake Superior shoreline. The Houghton County landscape is a product of all of the major glacial episodes of the Pleistocene epoch, and deglaciation at about 10,000 B.P. About 85% of the land area in Houghton County is classified as forest-woodland (*5*).

A National Cooperative Soil Survey was 80% complete when research began in June

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