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EVALUATING LEK OCCUPANCY OF GREATER SAGE-GROUSE IN RELATION TO LANDSCAPE CULTIVATION IN THE DAKOTAS

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ABSTRACT.—Greater Sage-Grouse (*Centrocercus urophasianus*) have been declining in many states and provinces of North America, and North and South Dakota hold no exception to these declines. We studied effects of cultivated land on Greater Sage-Grouse lek abandonment in North and South Dakota. Landscape-level data were assessed using satellite imagery within a geographic information system. Comparisons were made of 1972–1976 and 1999–2000 percent cultivated and noncultivated land. These comparisons were made between land uses surrounding active leks versus inactive leks, active leks versus random locations, and abandoned regions versus active regions. The 1999–2000 imagery illustrated that percent cultivated land was greater near abandoned leks (4-km buffers) than near active leks in North Dakota or random sites, but this did not hold true in South Dakota. Comparison of an extensive region of abandoned leks with a region of active leks in North Dakota illustrated a similar increase as well as dispersion of cultivation within the abandoned region. However, 1972–1976 imagery revealed that this relationship between percentage of cultivated land and lek activity in North Dakota has been static over the last 30 years. Thus, if the decline of Greater Sage-Grouse is the result of cultivated land infringements, it occurred prior to 1972 in North Dakota.

Key words: Greater Sage-Grouse, lek, North Dakota, satellite imagery, South Dakota.

Greater Sage-Grouse (*Centrocercus urophasianus*) populations in western North America were once widely distributed through 13 states as far south as Arizona and north into 3 provinces of Canada (Braun 1995, Connelly and Braun 1997, Schroeder et al. 1999, Young et al. 2000). The overall decline of this species began near the onset of the 20th century, probably due to agricultural practices, over-shooting, and increasing numbers of livestock (Patterson 1952, Dalke et al. 1963, Gill 1966). This decline continued throughout the 1900s in most of the Greater Sage-Grouse range and has been primarily attributed to decreasing amounts of sagebrush (*Artemisia* spp.) due to agriculture (i.e., cash crops), herbicides, over-grazing, energy development, fire, and/or drought (Patterson 1952, Homer et al. 1993, Gregg et al. 1994, Connelly and Braun 1997, Braun 1998, Connelly et al. 2000). There have been documented decreases in Greater Sage-Grouse populations after the plowing of sagebrush habitat in Montana (Swenson et al. 1987).

Information on historical Greater Sage-Grouse distribution and landscape trends is vital to understanding the bird's decline and to Greater Sage-Grouse conservation efforts.

Greater Sage-Grouse generally use open areas with good visibility for their breeding and display sites (Patterson 1952, Gill 1966), otherwise known as leks. Depending on when they are made, Greater Sage-Grouse counts are the best index to breeding population numbers (Connelly and Braun 1997). Greater Sage-Grouse need sagebrush cover and/or other shrubs adjacent to leks for escape cover from predators, particularly Golden Eagles (*Aquila chrysaetos*; Scott 1942, Enyeart 1956). Daily movements of male Greater Sage-Grouse from the lek during the breeding season were found to average 1.3 km in Montana (Wallestad and Schladweiler 1974). When shrub coverage near leks is removed due to tillage, fire, or spraying, it leaves Greater Sage-Grouse at these sites vulnerable to harassment from predators (e.g., Golden Eagles) and may cause abandonment

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(Eneyart 1956, Peterson 1970) or changes in timing and size of male Greater Sage-Grouse lek attendance (Boyko et al. 2004). Sagebrush coverage is not only important for breeding activities, but nesting activities as well (Connelly et al. 1991, 2000). Wallestad and Pyrah (1974) observed that 68% of nests were within 2.5 km of the lek site where females bred in central Montana. Aldridge (2000) found an average lek-to-nest distance of 4.7 km in Alberta. Wakkinen et al. (1992) discerned that 92% of nests were ≤ 3 km from leks where females bred in Idaho. Breeding to nesting site movements generally range from 1.1 km to 6.2 km, but can be >20.0 km (Connelly et al. 2000).

To identify habitat/land use change in large areas, such as those that Greater Sage-Grouse encounter, many scientists are now incorporating satellite imagery as a valuable tool (Homer et al. 1993, De'ath and Fabricius 2000, Debeljak et al. 2001). One approach, as used in our study, is to apply satellite imagery in making landscape-scale comparisons between areas around historical but now abandoned Greater Sage-Grouse leks and areas with currently active leks. The objective of this study was to compare current and historical (prior to 2000) distributions of Greater Sage-Grouse leks in relation to landscape cultivation in North and South Dakota.

STUDY AREA

The study area was located in extreme western South Dakota in Fall River, Butte, and Harding Counties and in southwestern North Dakota in Bowman, Slope, and Golden Valley Counties. Elevation in the South Dakota study area ranges from 525 m to 1050 m above sea level; the area has an overall topography of unglaciated rolling prairie with occasional buttes and intermittent streams (Johnson 1976, 1988, Kalvels 1982). Annual precipitation ranges from 37.4 cm to 41.8 cm, with approximately 80% of precipitation from April to September (Johnson 1976, 1988, Kalvels 1982). Annual summer temperature ranges from a low of 14.3° to a high of 31.1°C and winter temperature ranges from -14.6° to 1.4°C (Johnson 1976, 1988, Kalvels 1982).

Elevation in the North Dakota study area is 640 m to 1045 m above sea level; general topography is much like the South Dakota study area but with pinnacles, domes, canyons, gorges,

ravines, and gullies associated with the Badlands (Opdahl et al. 1975, Thompson 1978, Aziz 1989). Annual precipitation ranges from 35.6 cm to 40.6 cm, with approximately 80% occurring from April to September (Opdahl et al. 1975, Thompson 1978, Aziz 1989). Annual summer temperature ranges from 9.9° to 27.5°C and winter temperature ranges from -15.6° to 0.2°C (Opdahl et al. 1975, Thompson 1978, Aziz 1989). Our study area vegetation communities consisted of a mixture of shrubs including big sagebrush (*A. tridentata*), silver sagebrush (*A. cana*), and greasewood (*Sarcobatus vermiculatus*); perennial grasses including Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*Agropyron smithii*), and Japanese brome (*Bromus japonicus*); forbs including common dandelion (*Achillea millefolium*), common yarrow (*Taraxacum officinale*), and cudweed sagewort (*Artemisia ludoviciana*); cash crops (corn, wheat, and alfalfa); cultivated land; and open grassland. The study area falls within the big sagebrush-wheatgrass plains vegetation type (Johnson and Larson 1999).

METHODS

Background

An active Greater Sage-Grouse lek is a traditional communal display ground for breeding Greater Sage-Grouse that "has been attended by ≥ 2 male Sage-Grouse [sic] in ≥ 2 of the previous 5 years" (Connelly et al. 2000:9). A Greater Sage-Grouse lek would be labeled inactive when the criteria for an active lek do not hold true. A historically active lek would have been active at one time but was inactive at the time of the study. Statistical significance was set at $\alpha = 0.10$.

Cultivated Land Classification

We recorded and assessed landscape-level data within 4-km buffers and regions using satellite imagery [i.e., LANDSAT 7 Thematic Mapper (TM) Imagery] obtained from Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, South Dakota, within a geographic information system (GIS). GIS coverages permitted evaluation of landscape-level differences between active and inactive leks (Oklahoma Department of Wildlife Conservation 1998). Satellite imagery was classified into 2 categories: cultivated land and noncultivated

land. Three scenes of 1972–1976 and 1999–2000 satellite imagery that covered our study areas were classified into cultivated and non-cultivated land using ERDAS Imagine Software 8.5 (ERDAS® Inc., Atlanta, GA, USA). The 1972–1976 year range was selected because it was the farthest we could go back with usable satellite imagery for our study area with different years available for different counties, and the 1999–2000 year range was selected because it was the most current satellite imagery we could obtain with different years available for different counties from EROS Data Center. We used the area of interest tools in ERDAS Imagine to perform a supervised classification on areas believed to be cultivated land. We then used aerial photos obtained from county Natural Resources Conservation Service and Farm Service Agency offices to check our interpretation of the imagery. Ground truthing of imagery was also incorporated with >80% mapping accuracy within the analyzed areas. These classified satellite images were converted to a 60 × 60-m grid within Imagine. The grid was then brought into ArcView 3.2a for analysis. We calculated percentage of total cultivated and noncultivated area within 4-km buffers around active and inactive leks in North and South Dakota, within 2-km buffers around random points in an extensive active region and inactive region in North Dakota, and for the entire active versus inactive region in North Dakota for years 1972–1976 and 1999–2000. All data were analyzed in SAS (SAS Institute 1999) and maps were displayed using Clarke 1866 ellipsoid, North American Datum 1927, and projection UTM Zone 13.

4-km Buffer Comparisons

Active and inactive leks were plotted onto a map of the study area in North and South Dakota (Fig. 1). We buffered active and inactive leks and randomly selected points by a 4-km radius. Using the low end and the high end of the average nest distance from the nearest lek (Connelly et al. 2000), we took the mean of these 2 distances which rounded up to 4 km. Preliminary landscape-level plotting indicated that buffering >4 km also caused too much overlap between sites for significant comparisons to be made. If an active 4-km buffer overlapped an inactive 4-km buffer by more than 1 km, we ignored the inactive one

because we felt that the area within the inactive buffer may still be used by Greater Sage-Grouse from the active lek. If both were inactive or active, we assigned one buffered area odd numbers and the other area even numbers and used a random number generator to choose the one to be ignored. If they overlapped <1 km, the buffers were treated as if they were independent. We used ArcView 3.2a random point generator to select random locations in the study area within the historical range (Schroeder et al. 2004) of Greater Sage-Grouse leks in North and South Dakota. Because of extensive coverage of leks in North Dakota, random points were selected without regard to overlap with 4-km buffers of active or inactive lek sites. We compared current (1999–2000) percent cultivated and noncultivated land with active and historically active buffered areas. We also compared historic (1972–1976) percent cultivated and percent noncultivated land within 4-km buffers of leks that were active in 1972–1976 with those that were inactive in 1999–2000. Leks that have remained active in the comparison have not moved significantly (>0.5 km) from their location in the early 1970s. We overlaid our buffers onto our grids of 1972–1976 and 1999–2000 cultivated and noncultivated land in North Dakota and South Dakota within ArcView 3.2a (Environmental Systems Research Institute, Inc., Redlands, California, USA, 1992–2002). Percent area of cultivated and noncultivated land was then calculated using the tabulate area option within the grid analyst extension of ArcView 3.2a. Active, inactive, and random buffers were then compared using a paired *t* test. Due to unequal variances determined from the folded F-statistic, a degrees-of-freedom adjustment using the Satterthwaite method was used on *t* tests (SAS Institute 1999). Additionally, we compared (paired *t* tests) the percentage of cultivated land within the 4-km buffers around active leks in North Dakota and South Dakota with that of leks with ≥40 male Greater Sage-Grouse (we considered this a good active lek) in eastern Montana. We used large Greater Sage-Grouse leks in Montana to obtain a comparison of the habitat around large leks more in the central part of the Greater Sage-Grouse range. We obtained and classified Montana satellite imagery in the same way as North and South Dakota imagery explained previously.

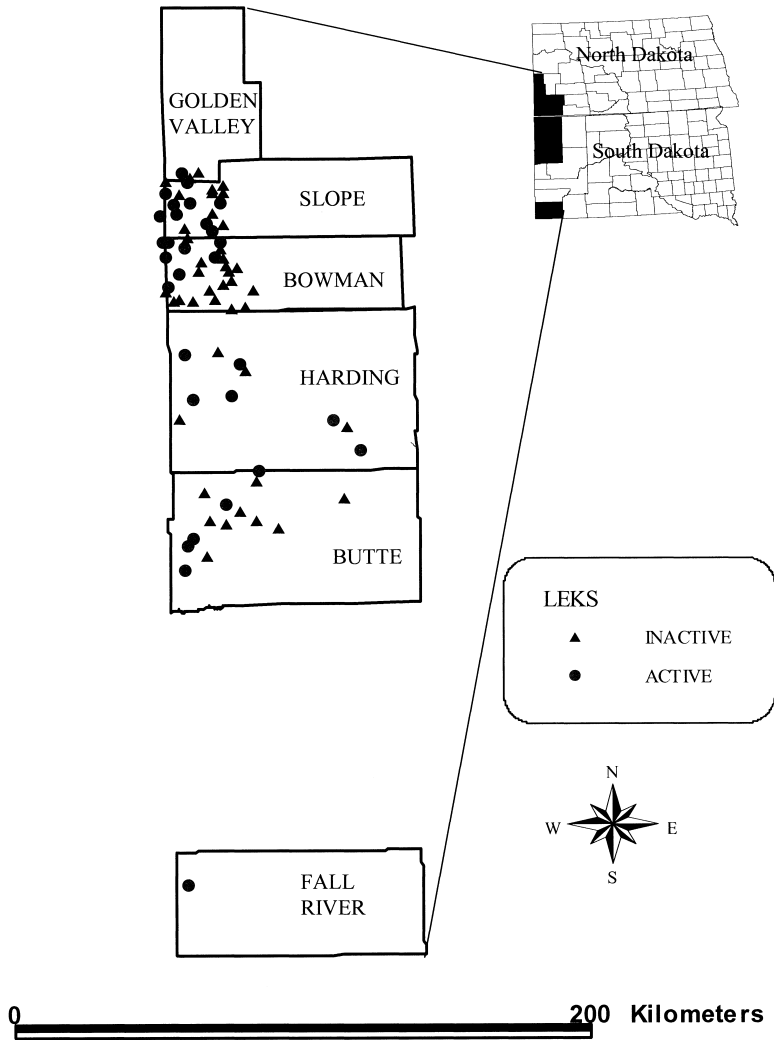


Fig. 1. Inactive and active Greater Sage-Grouse lek locations within North and South Dakota.

Region Comparisons

In North Dakota we identified 2 geographic regions, 1 with 100% inactive leks and 1 with 73% active leks, and enclosed each within a polygon (Fig. 2). We were unable to identify similar active and inactive lek regions in South Dakota due to lack of historical lek location information and defined regions of lek abandonment and activity. These regions in North Dakota were compared relative to the current (1999–2000; Fig. 3B) and historic (1972–1976; Fig. 3A) percent cultivated land within each region. Within ArcView 3.2a, the active and

inactive regions we created in North Dakota were overlaid onto the grid of cultivated land. Percent cultivated and noncultivated lands were calculated within each region using the tabulate area method. These percentages were then compared between regions and between years using a goodness-of-fit chi-square test.

Random points were established within the active and inactive regions in North Dakota to evaluate dispersion of cultivation. An increase in proportion of buffered random points with cultivation would also relate directly to increased shrubland-cultivation edge, an indication of shrubland fragmentation. We created

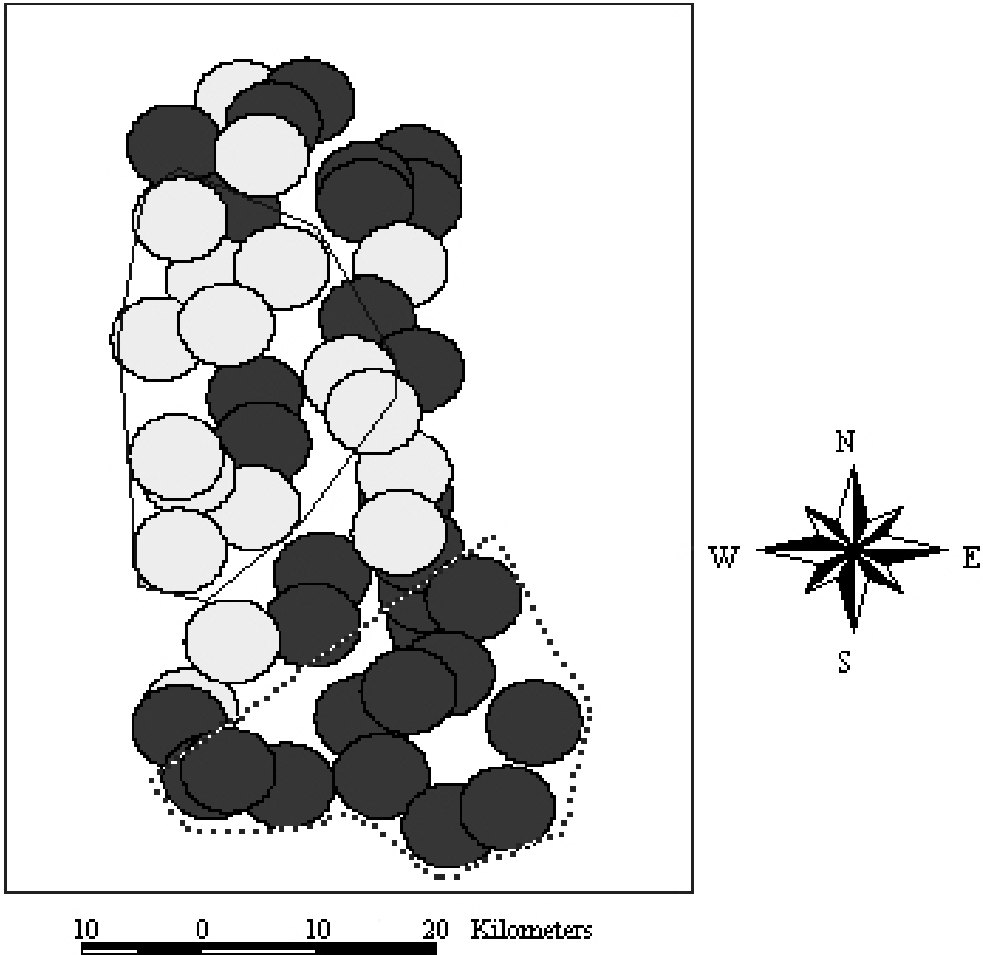


Fig. 2. Regions created in North Dakota by placing polygons around 4-km buffers of Greater Sage-Grouse leks. Buffers are designated as active (light gray filled circles) or inactive (dark gray filled circles).

2-km buffers around 15 randomly placed points within each region and overlaid them onto the grids of 1972–1976 (Fig. 4A) and 1999–2000 (Fig. 4B) percent cultivated land. For regional comparisons we used 2-km buffers to balance the need to sample landscapes with the need for more points to better sample area. The percentage of the 15 randomly placed buffers within each region containing cultivated land (>0 ha) and the percentage of the 15 randomly placed buffers containing no cultivated land within each region were compared between regions and between years using a chi-square test.

RESULTS

Comparisons of 4-km Buffers for 1999–2000

Comparisons of percent cultivated land within 4-km buffers around active leks and inactive leks (Table 1) in North Dakota revealed that inactive leks had a higher ($|t| = 3.03$, 12 df, $P = 0.0105$) percentage of cultivated land than active leks. Percent cultivated land within 4-km buffers around random points (Table 1) was also found to be higher ($|t| = 2.47$, 25 df, $P = 0.0204$) than 4-km buffers around active sites in North Dakota.

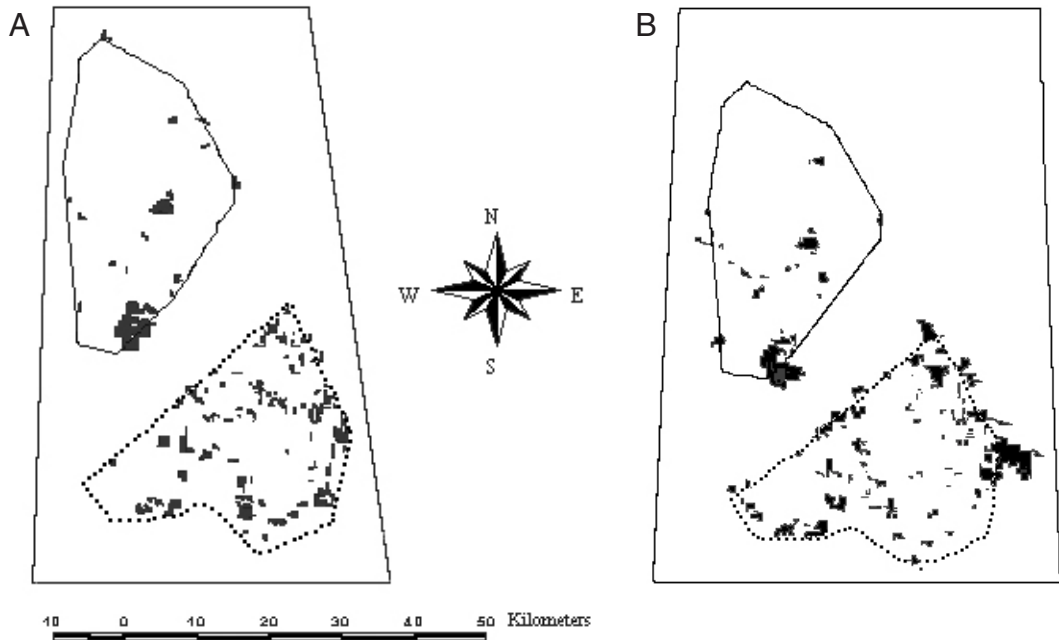


Fig. 3. Active (polygon with solid outline) and inactive (dotted outline) regions in North Dakota overlaid onto 1972–1976 (A) and 1999–2000 (B) grids of cultivated (black areas) and noncultivated (white areas) ground. Only cultivated ground intersecting or within regions is shown on 1972–1976 grid.

Comparisons of percent cultivated and noncultivated land within 4-km buffers placed around active leks and inactive leks (Table 1) in South Dakota revealed that inactive leks showed no difference ($|t| = 0.35$, 17 df, $P = 0.7327$) in percentage of cultivated land from that within 4-km buffers of active leks. Percent cultivated land within 4-km buffers around random points (Table 1) was no different ($|t| = 1.20$, 23 df, $P = 0.2427$) from percent cultivated land within 4-km buffers around active sites in South Dakota. Comparisons of percent cultivated land within 4-km buffers placed around active leks in eastern Montana (Table 1) versus active leks in the Dakotas showed no difference (North Dakota: $|t| = 0.24$, 12 df, $P = 0.8141$; South Dakota: $|t| = 1.36$, 11 df, $P = 0.2012$).

Comparisons of 4-km Buffers Between 1972–1976 and 1999–2000

The percentage of cultivated land within 4-km buffers around leks that were active in 1972–1976 and inactive in 1999–2000 (Table 2) showed no difference (North Dakota: $|t| =$

1.14, 4 df, $P = 0.3188$; South Dakota: $|t| = -1.00$, 5 df, $P = 0.3632$) between periods. The percentage of cultivated land within 4-km buffers around leks that were active in 1972–1976 and were still active in 1999–2000 (Table 2) also showed no difference (North Dakota: $|t| = 0.91$, 3 df, $P = 0.4290$; South Dakota: $|t| = -1.00$, 3 df, $P = 0.3910$) between periods.

Region Comparisons

Region comparisons in North Dakota revealed that the proportion of cultivated land (area of cultivated/area of noncultivated) in 1999–2000 was greater ($\chi^2 = 2.9563$, 1 df, $P = 0.0855$) within the inactive region than within the active region (Fig. 5A). The landscape in 1999–2000 within the inactive region also had a greater ($\chi^2 = 59.2741$, 1 df, $P < 0.0001$) percentage of occurrence of cultivated land (i.e., buffers with cultivated land/15) within the 15 random 2-km buffers than the 15 random 2-km buffers within the active region (Fig. 5B).

Between 1972–1976 and 1999–2000, the proportion of cultivated land to noncultivated land within the inactive and active region of North Dakota (Fig. 5A) showed no change

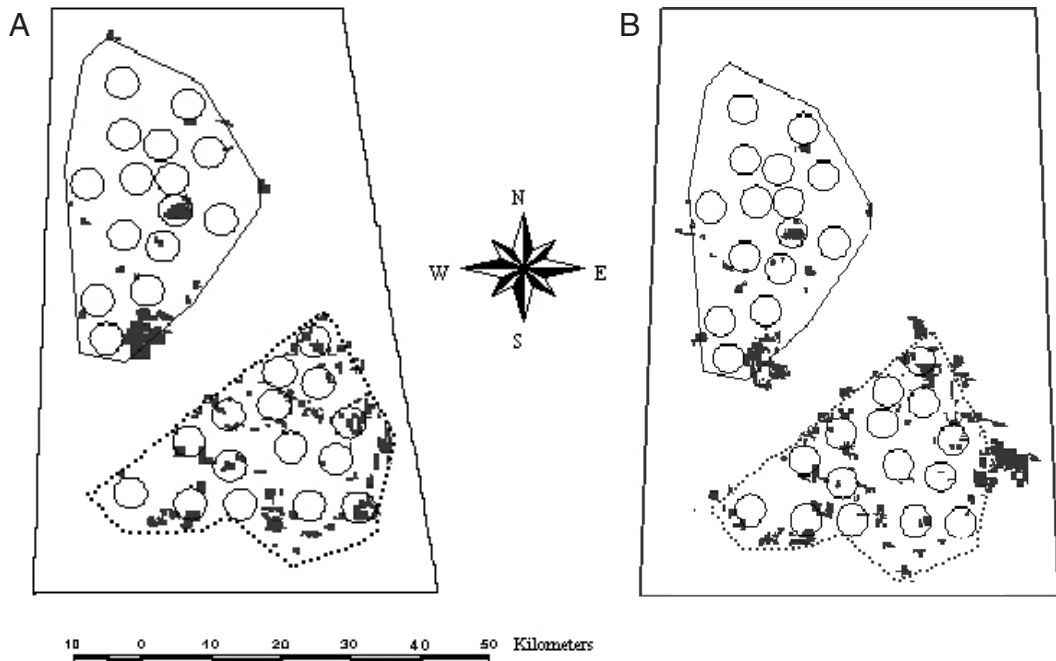


Fig. 4. Random points ($n = 15$) buffered by 2 km (circles) within each region (solid-line polygon = active; dotted-line polygon = inactive) and overlaid onto 1972–1976 (A) and 1999–2000 (B) grids of cultivated (black areas) and noncultivated (white areas) ground. Only tilled ground intersecting or within regions is shown on 1972–1976 grid.

(inactive: $\chi^2 = 0.0725$, 1 df, $P = 0.7877$; active: $\chi^2 = 0.0398$, 1 df, $P = 0.8418$). Buffers around our 15 randomly placed points within the inactive and active regions of North Dakota (Fig. 5B) also showed no change in cultivation (inactive: $\chi^2 = 1.6017$, 1 df, $P = 0.2057$; active: $\chi^2 = 0.9579$, 1 df, $P = 0.3277$) between 1972–1976 and 1999–2000.

DISCUSSION

From current (1999–2000) satellite imagery, it appears that cultivated land plays a role in lek abandonment in North Dakota. However, when we investigated the relationship, comparing early satellite imagery (1972–1976) to more recent imagery (1999–2000), there was no increase in the amount of cultivated land associated with the inactive areas since the early to mid-1970s. If cultivated land is a factor in the abandonment of leks, its effects likely began before 1972–1976. Greater Sage-Grouse are influenced by landscape-scale changes (Connelly et al. 1988, Crawford et al. 2004) that may result from tillage (Peterson 1970), fire

(Nelle et al. 2000), or other disturbances of sagebrush ecosystems (Haegen et al. 2002). Increases in cultivation activity have been found to cause Greater Sage-Grouse declines in the State of Washington (Schroeder et al. 2000). These disturbances may affect female nesting sites (Call and Maser 1985), causing females to shift to undisturbed areas and thus decreasing lek size or resulting in abandonment if males shift the lek site closer to the location of high female abundance (Bradbury et al. 1986, Gibson 1996).

We cannot detect a relationship between cultivated land and abandonment of leks in South Dakota; however, from the limited historical information available, more leks may have been present in regions farther east where cultivation has been more common. In South Dakota, removal of sagebrush through cultivation and herbicides may still be a factor in the abandonment of Greater Sage-Grouse leks. In North Dakota there are historical leks but no known active leks located in areas of Bowman County where intensive cultivation practices are present. The same relationship may hold

TABLE 1. Percent cultivated land within 4-km buffers placed around active leks, inactive leks, and random points in North Dakota (ND), South Dakota (SD), and Montana (MT), 1999–2000.

State	Status ^a	<i>n</i>	% cultivated	
			\bar{x}	$s_{\bar{x}}$
ND	A	12	3.79	0.83
	I	10	10.47	2.04
	R	18	8.08	1.52
SD	A	11	0.95	0.44
	I	8	0.83	0.64
	R	18	2.04	0.96
MT	A	11	4.43	2.52

^aA = active lek, I = inactive lek, and R = random points.

TABLE 2. Percent cultivated land within 4-km buffers placed around leks active in 1972–1976 that were active or inactive in 1999–2000 in North Dakota (ND) and South Dakota (SD).

State	Status ^a	<i>n</i>	% cultivated			
			1972–1976		1999–2000	
			\bar{x}	$s_{\bar{x}}$	\bar{x}	$s_{\bar{x}}$
ND	A	4	2.44	1.46	2.07	1.15
	I	5	8.53	3.54	5.16	1.69
SD	A	4	0.19	0.19	0.23	0.23
	I	5	0.00	0.00	0.61	0.61

^aA = active lek, I = inactive lek.

true for South Dakota. No active leks were found in northeastern Harding County and southeastern Butte County, both regions of higher cultivation than other regions of these counties with active leks. However, we lack consistent historical records to determine if leks were ever present in these regions of Butte and Harding Counties.

Other studies suggest that Greater Sage-Grouse movement from one lek to another could be in response to a combination of factors. Distance may not be a factor in movements, but prior habitat alterations and topography might play important roles (Emmons and Braun 1984). Habitat alterations around the lek (e.g., plowing, spraying, burning, and overgrazing) could initiate abandonment (Wallestad and Schladweiler 1974, Call and Maser 1985, Crawford et al. 2004). These disturbances may not directly harm Greater Sage-Grouse, but when these activities cause the eradication of sagebrush and fragmentation of habitat around strutting grounds, they have been documented to cause abandonment and an overall decrease in the population of that area (Enyeart 1956,

Wallestad 1975). Further, disturbance to the central part of the Greater Sage-Grouse range and adjoining areas of Montana and Wyoming could be weakening peripheral populations in North and South Dakota. Other activities known to affect fidelity to displaying areas are mining, oil wells, and military disturbance (Rogers 1964, Eng et al. 1979, Tate et al. 1979, Call and Maser 1985, Schroeder et al. 1999), mainly due to the noise level (Rogers 1964) or to new perching sites provided for raptors that may disturb Greater Sage-Grouse breeding displays.

Increased disturbance to Greater Sage-Grouse leks by roads, oil and natural gas wells/pumps, and associated noises may be playing a role in lek abandonment in North Dakota. These wells and pumps have sometimes been within 100 m of, if not directly on, Greater Sage-Grouse lek sites. Oil well development within 200 m may have caused abandonment of at least 1 lek in North Dakota (Jerry Kobriger, personal communication, North Dakota Game and Fish Department). However, oil/natural gas wells and power lines are located within 500 m of both currently active leks (6) and

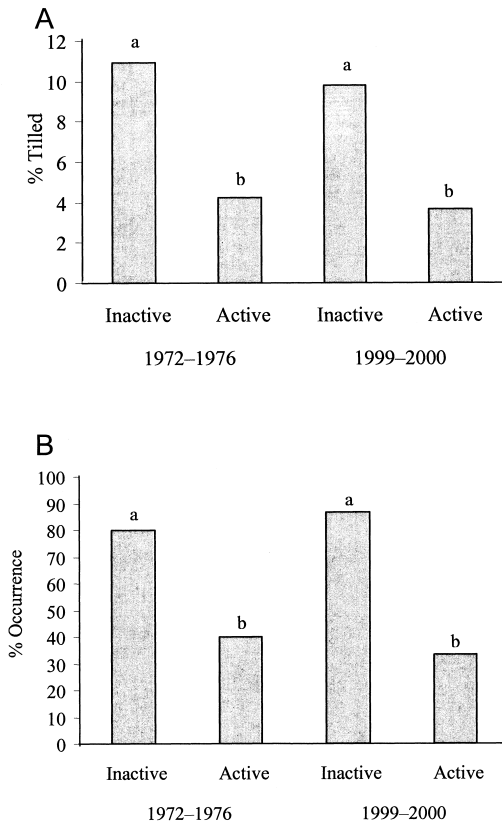


Fig. 5. Comparison of 1972–1976 and 1999–2000 percent cultivated land within active and inactive regions in North Dakota. A, Total percent of cultivated land within each region; B, percent of the 15 random 2-km buffers that had cultivated land within them. Same letters indicate no significant difference.

inactive leks (4) in the Dakotas. We observed 2 strutting grounds within 200 m of oil wells that were erected during the 2 years of the study. Whether these leks will remain active in these same areas is yet to be determined. Proximity of oil/natural gas wells is also associated with other disturbances and landscape changes that could discourage lek use. To extract their product from these wells, companies have been building numerous roads through areas occupied by Greater Sage-Grouse. The physical presence of roads themselves may not immediately detract male and female Greater Sage-Grouse from an area, but dust and noise may eventually cause shifts or abandonment. Future studies in the Dakotas may

be justified to examine the proximity of such disturbances to Greater Sage-Grouse activities.

In the Dakotas most of the Greater Sage-Grouse breeding range falls on private land, so working locally and inviting all potential stakeholders to conservation planning meetings is a must and may prove crucial in accomplishing habitat recovery. Some leks may need to be managed differently from others to meet conservation goals as well as local landowner objectives. Sustained efforts at restoration of Greater Sage-Grouse habitat are needed to minimize degradation and further habitat loss on private and even public lands (Wisdom et al. 2002). Programs like the Conservation Reserve Program have helped in grassland bird habitat recovery (Herkert 1998, McCoy et al. 1999). Similar programs to reestablish sagebrush communities or systems in areas converted to cropland might be beneficial to Greater Sage-Grouse. Areas that have soils suited to establishing sagebrush will have the best potential for Greater Sage-Grouse habitat reclamation. By translating the conservation value of sagebrush range to economic values (Olson 1996) captured by the landowner through innovative processes and habitat restoration incentive programs, we can help residents of rural communities meet their needs of earning a living while maintaining Greater Sage-Grouse population.

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