CURRENT STATUS AND APPROACHES TO MONITORING POPULATIONS AND HABITATS OF GREATER PRAIRIE CHICKENS IN OKLAHOMA

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1977

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1980

CURRENT STATUS AND APPROACHES TO MONITORING

POPULATIONS AND HABITATS OF GREATER

PRAIRIE CHICKENS IN OKLAHOMA

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PREFACE

The purpose of this study was to provide current information on greater prairie chickens in Oklahoma for use by the Oklahoma Department of Wildlife Conservation. Techniques to monitor habitat and population trends were also investigated.

Financial support was provided by Federal Aid in Wildlife Restoration, P. R. Project Oklahoma W-125-R, Oklahoma Department of Wildlife Conservation, and Oklahoma State University, cooperating.

I wish to express my sincere appreciation to my major advisor, Dr. Fritz L. Knopf, Assistant Professor, Department of Ecology, Fisheries, and Wildlife, for his trust and guidance during the study, and assistance in preparing this thesis. I also wish to thank Dr. Paul A. Vohs, Leader, Oklahoma Cooperative Wildlife Research Unit, and Dr. John A. Bissonette, Assistant Leader, Oklahoma Cooperative Wildlife Research Unit, for their suggestions and assistance during the study, and for serving as members of my graduate committee.

A special thanks is extended to the innumerable landowners who graciously provided access to the study areas and the individuals who responded to continuous queries about the birds. Additional thanks to Larry R. Pettinger, Applications Scientist, EROS Data Center, for his tireless assistance with the Landsat analyses, and James C. Holada, Commercial Pilot, for his continuous display of professionalism and skills while in flight. Michael E. O'Meilia volunteered as observer during the second field season and provided his friendship in numerous endeavors throughout the study. Mark Williams served as observer during both field seasons.

Finally, my deepest appreciation is to my wife, Benetta, for keeping me, and caring for me throughout this study.

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CHAPTER I

INTRODUCTION

This thesis comprises 3 manuscripts written in formats suitable for submission to national scientific journals. The manuscripts are presented as chapters in the thesis, each complete without additional supporting materials. The manuscript "Distribution and numbers of greater prairie chickens in Oklahoma" (Chapter II) was written in the format of the WILDLIFE SOCIETY BULLETIN. The manuscript "Aerial survey of greater prairie chicken leks" (Chapter III) was written in the format of the WILDLIFE SOCIETY BULLETIN. The manuscript "Evaluation of habitats of greater prairie chicken populations in Oklahoma with emphasis on Landsat applications" (Chapter IV) was written in the format of THE JOURNAL OF WILDLIFE MANAGEMENT. The legal description of each study area (Appendix) is provided for future reference.

CHAPTER II

DISTRIBUTION AND NUMBERS OF GREATER PRAIRIE CHICKENS IN OKLAHOMA

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Abstract: Distribution and numbers of greater prairie chickens (*Tympanuchus cupido pinnatus*) in Oklahoma were estimated during a 2-year study (1977-79). An estimated 8,415 birds occupied 6,100 km^2 in 13 northeastern counties. Although status varied in counties occupied by prairie chickens, the general trend indicated a 42% decrease in occupied range and 34% decrease in numbers since 1943. The population can be divided into a relatively stable western component and a rapidly declining eastern component. Declines in the eastern component appear related to more intensive agricultural

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development in those counties.

The geographic range of the greater prairie chicken (Tympanuchus cupido pinnatus) historically included portions of Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Missouri, Nebraska, Ohio, Oklahoma, and Texas (Baker 1953, Johnsgard 1975) and may have extended eastward into extreme western Pennsylvania (Schwartz 1945). In the early 1900's, greater prairie chickens increased in response to the abundant winter foods provided by the agricultural practices of settlers. However, as native tall grass prairie disappeared with tillage, numbers of prairie chickens decreased (Duck and Fletcher 1944, Mohler 1952, Hamerstrom and Hamerstrom 1961, Aldrich 1963, Evans and Gilbert 1969).

In Oklahoma, the greater prairie chicken coexisted with lesser prairie chickens (T. pallidicinctus), sharp-tailed grouse (Pediocetes phasianellus), and sage grouse (Centrocercus urophasianus) in the early 1900's (Nice 1931). Greater prairie chickens were abundant throughout the eastern two-thirds of the state and reached peak numbers around the early 1900's (Duck and Fletcher 1944). By 1925, habitat destruction resulting in loss of rangeland had severely reduced the population in many counties. Prairie chicken populations continued to decline in distribution and population levels through 1958 (Jacobs 1959). This paper describes the current distribution and population numbers of greater prairie chickens in Oklahoma based upon information collected from October 1977 to June 1979.

We thank P. A. Vohs and J. A. Bissonette for their assistance in coordination of the project. This paper is a contribution from Federal Aid in Wildlife Restoration; P. R. Project Oklahoma W-125-R, Oklahoma Department of Wildlife Conservation, and Oklahoma State University, cooperating.

METHODS

Questionnaires were mailed during fall, 1977 to Game Rangers, Area Managers, and Biologists of the Oklahoma Department of Wildlife Conservation. Background requests included geographical area of responsibility and length of time having worked in the area. Biological considerations included the location of flocks and the approximate number of birds in each, stability of the population, and designation of areas thought to possess increasing or decreasing populations. We asked individuals to comment about factors believed to be limiting populations of prairie chickens in the area.

Recipients of questionnaires were asked to identify landowners who might be approached concerning additional information about flocks. Farmers and ranchers were contacted initially during winter 1977, while others were contacted during spring, 1978 and 1979. Information collected from these individuals included locations of flocks and population estimates. We collected supplemental information with field visits during both springs.

Cumulative population data were plotted on detailed county road maps. Information was compiled to provide a distribution and nonstatistical estimate of numbers for each county. Areas providing "potential" habitats were excluded.

Field investigations using ground counts and aerial surveys were conducted on 7 selected study areas during the spring 1978 and 1979 to determine lek densities (Martin and Knopf, ms). These observations were used for comparison with estimated population numbers of prairie chickens on each study area. Population estimates from data generated by interviews were available for 3 study areas exclusively. Estimates of population numbers on the remaining 4 study areas were calculated from estimates on areas larger than each specific study area.

RESULTS

A spring population of 8,415 greater prairie chickens currently inhabits 6,100 km^2 in Oklahoma. The largest continuous distribution is in eastern Kay and northwestern Osage counties (Fig. 1). Kay County supports 500 birds on 730 km^2 and Osage County maintains 3,000 birds on 1,690 km^2.

Several scattered "populations" occur elsewhere in the state. The population in Noble and Pawnee counties includes 1,150 birds that range over 665 km^2. The larger populations occurring predominantly in Craig, Mayes, Rogers, and Nowata counties include 3,100 birds collectively over a 2,745 km^2 range. An additional 615 birds occur on 270 km^2 in isolated populations in Payne, Tulsa, and Ottawa counties.

Comparisons of these data with intensive field investigations indicated study areas 1,5, and 8 were reported to possess 200, 50, and 100 birds, respectively. Field investigations revealed 163, 64, and 120 birds for these areas, respectively. Areas 2 and 3 were estimated at possessing 74 birds each from average estimates for Osage County. Field investigations reported 75 and 38 birds, respectively. Areas 4 and 7 were estimated to contain 64 and 47 birds, respectively, however,

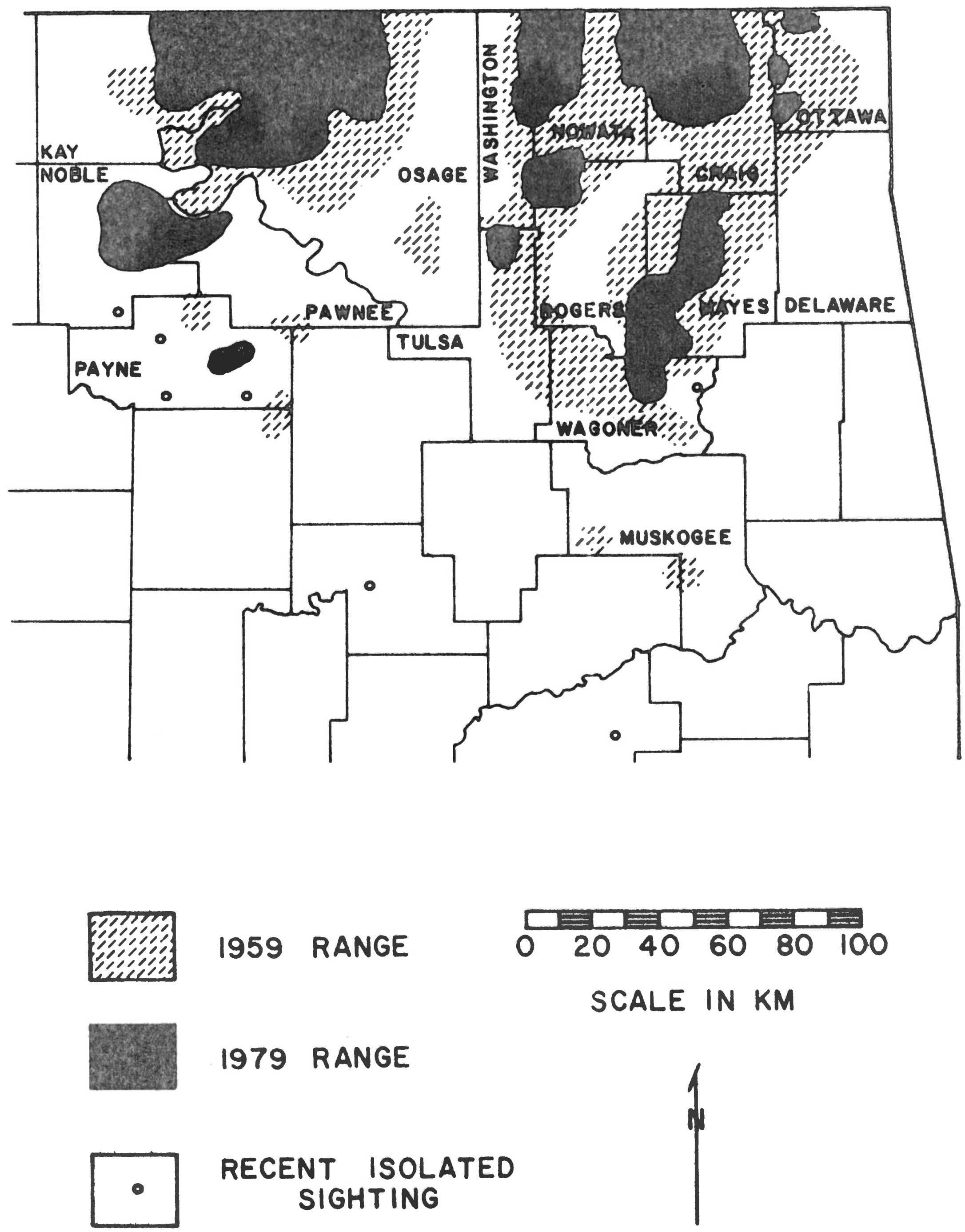

Fig. 1. Distribution of the greater prairie chicken in northeastern Oklahoma.

intensive surveys indicated 8 and 127 birds, respectively.

DISCUSSION

Geographic Range

The range of the greater prairie chicken in Oklahoma has declined to a portion of that described in 1943 (Table 1) by Duck and Fletcher (1944) and in 1958 (Fig. 1) by Jacobs (1959). The estimate of occupied range in the state was reduced 42% from 10,530 km^2 in 1943 to 6,100 km^2 in 1979.

In the western portion of the range, greater prairie chicken populations appear stable. The Osage County range of 1,690 km^2 corresponds to that of 1958, whereas it represents a 35% decrease from 1943. The birds in Noble County were not reported in either of the earlier studies, and residents feel that chickens first appeared during the last 10-15 years. Pawnee and Payne counties demonstrated decreases in range of 76% and 91%, respectively. Greater prairie chickens were not reported in Kay County in 1943, although Jacobs illustrated a 1958 distribution there larger than the current range.

For the eastern part of the state, greater prairie chickens occupy only scattered remnants of the range reported by Jacobs (1959). Increases of 99% in Craig County and 254% in Rogers County since 1943 were noted. However, these increases were exceptions. Thirty-three to 81% reductions in range were seen in Mayes, Nowata, Ottawa, Tulsa, Wagoner, and Washington counties since 1943. The decline in these 6 counties totals over 2,900 km^2. Few prairie chickens were located in Muskogee County despite a 1,077 km^2 range in 1943.

Table 1. Comparison of the historical and contemporary (1979) estimates for range and population numbers of the greater prairie chicken in Oklahoma.

County	Historical summary (1944)		Current status (1979)		Percentage change	
	Population	Range (km^2)	Population	Range (km^2)	Population	Range
Craig	3,348	440	1,000	875	-70	+99
Kay	-	-	500	730	+	+
Mayes	1,346	870	450	585	-66	-33
Muskogee	70	1,077	50	-	-29	-100
Noble	-	-	750	480	+	+
Nowata	1,689	1,295	800	605	-53	-53
Osage	2,958	2,590	3,000	1,690	+1	-35

Table 1. (Continued)

County	Historical summary (1944)		Current status (1979)		Percentage change	
	Population	Range (km^2)	Population	Range (km^2)	Population	Range
Ottawa	821	492	550	115	-33	-77
Pawnee	176	780	400	185	+127	-76
Payne	165	922	15	80	-91	-91
Rogers	1,206	96	350	340	-71	+254
Tulsa	70	388	100	75	+43	-81
Wagoner	566	700	200	130	-65	-81
Washington	240	880	300	210	+25	-76
Total	12,655	10,530	8,415	6,100	-34	-42

Population Levels

Populations of greater prairie chickens decreased from estimates made in 1943 (Table 1) by Duck and Fletcher (1944). A statewide population of 12,655 birds in 1943 decreased 34% to a minimum of 8,415 birds in 1979. For the western portion of the range numbers of birds remained relatively stable in Osage County, while population gains in Kay, Noble, and Pawnee counties more than offset losses in Payne County.

Fewer prairie chickens currently inhabit the eastern counties. Most counties showed major declines in prairie chicken numbers. The slight increases in population numbers reported for Tulsa and Washington counties were insufficient to compensate these major losses.

Factors Influencing Populations Since 1943

Estimates of prairie chicken densities in the literature vary from 1.9 birds/km^2 for greater prairie chickens in Missouri (Schwartz 1945) to 3.9 birds/km^2 for Attwater's prairie chickens in southern Texas (Lehmann 1941). Current densities of greater prairie chickens in Oklahoma average 1.4 birds/km^2, ranging from 0.2 birds/km^2 in Payne County to 4.8 birds/km^2 in Ottawa County.

Declining populations of greater prairie chickens are often attributed to changes in land-use practices. Rangelands are critical to the birds, and population densities appear to fluctuate with variations in the quantity and/or quality of rangelands (Schwartz 1945, Hamerstrom et al. 1957, Christisen 1969, Arthaud 1971). The current status of the bird in Oklahoma well illustrates its sensitivity to rangeland condition.

Osage County remains the stronghold for greater prairie chickens in Oklahoma due to the predominance of native rangeland. Private landholdings are large and often held as trusts. These ranches appear to be grazed under proper range management practices. The range expansion of prairie chickens into Noble County supports this belief. Prairie chickens appear to have colonized Noble County from Osage County, and their distribution in Noble County is also centered upon the locations of a few major landholdings managed predominantly as grazing operations.

The eastern component of the greater prairie chicken range in Oklahoma appears to be a deteriorating habitat. Private landholdings are small relative to the western component. Grazing operations are still common in the north, but native grasses are occasionally replaced by tame grasses. In the southern counties row cropping predominates, possibly favored also by greater topsoil depth. These practices result in a decline of habitat due to imbalances in the rangeland/agriculture ratio for greater prairie chickens.

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CHAPTER III

AERIAL SURVEY OF GREATER PRAIRIE CHICKEN LEKS

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Standard methodology for monitoring prairie chicken populations includes counting of displaying males on lek sites (booming grounds) in the spring (e.g., Schwartz 1945, Baker 1953, Kirsch 1956, Hamerstrom and Hamerstrom 1973). Greater prairie chickens (Tympanuchus cupido pinnatus) inhabit some of the more remote areas of northeastern Oklahoma (Martin and Knopf, ms). Access to these areas for counting prairie chickens is difficult and frequently restricted due to the absence of roads plus the impassability of unimproved roads during rainy periods in spring. Man-hour requirements and total area of

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coverage become limiting factors to estimating prairie chicken numbers.

Techniques using aerial survey minimize accessibility hurdles to monitoring these populations. The recent analyses of Cannon (1980) indicate that number of leks on an area provides a reliable index to changes in breeding densities of prairie chickens. In this paper we evaluate aerial survey as a technique for counting leks on an area.

We thank P. A. Vohs and J. A. Bissonette, for assistance in coordination of the project. M. E. O'Meilia and M. Williams provided assistance as observers. This paper is a contribution from Federal Aid in Wildlife Restoration; P. R. Project Oklahoma W-125-R, Oklahoma Department of Wildlife Conservation, and Oklahoma State University, cooperating.

STUDY AREAS

The current range of the greater prairie chicken in Oklahoma (Martin and Knopf, ms) lies within Duck and Fletcher's (1943) Tallgrass Prairie and Postoak-Blackjack Forest game types and Bailey's (1976) Oak-Hickory Bluestem Parkland and Oak and Bluestem Parkland sections of the Prairie Parkland province. Personnel of the Oklahoma Department of Wildlife Conservation and individual landowners within this area were interviewed regarding the current status of greater prairie chicken populations. Eight areas of 16 sections (4,144 ha) each were selected as study sites based upon estimates of population densities. Of these sites, 2 areas were estimated to have low population numbers, 3 high numbers, and 3 were intermediate. The study areas were located in Craig, Mayes, Noble, Nowata, Osage, Rogers, and Wagoner counties.

METHODS

Beginning 1 February each year, prairie chickens were located on leks by auditory triangulation resulting in direct observation during the first 3 h of daylight. The location of each lek was recorded on topographical maps (Hamerstrom and Hamerstrom 1973). These ground surveys continued throughout the breeding season (until mid-May) except on dates of aerial surveys.

Study areas were surveyed with a Cessna 172, high-wing aircraft. Aerial surveys began 30 min after sunrise and required approximately an hour to cover an area. Not more than 2 areas were flown on any morning in order to coincide flights with attendance of birds on the lek sites. Each area was flown 3 times per season, with the second flight occurring during the anticipated peak of lek activity in late April. Successive flights on any area were at least 2 weeks apart.

Flights were made along adjacent north-south transects at 0.4 km intervals at an altitude of 25-50 m (Eng 1955). Two observers (in addition to the pilot and investigator) verbally relayed observations pertaining to the location of leks to the project investigator. All information was recorded on 1:24,000 scale topographical maps which were also used to assist the pilot in maintaining proper heading and spacing of transects.

RESULTS AND DISCUSSION

A lek was defined as any observation of 2 or more birds at a single location. Single birds often flushed from seemingly random sites during aerial surveys. These birds were not considered to represent leks. Although single males were observed displaying alone during ground counts, a lek (by definition a communal display) assumes the presence of 2 or more males.

Populations of prairie chickens on study areas varied from 6 displaying males on 1 lek to 145 on 22 leks in 1978, and from 38 birds on 4 leks to 120 on 15 leks in 1979 (Table 1). Aerial surveys failed to detect all leks. The maximum number of leks observed during any single flight was less (1978: $\underline{X}^2 = 21.0$, $\underline{P} < 0.005$; 1979: $\underline{X}^2 = 5.4$, $\underline{P} < 0.5$) than the number of leks known to occur on that area.

The accuracy of lek counts by aerial survey improved with the addition of information from successive flights. The most substantial "gain" in information came with a second flight on an area. The number of leks detected increased from single flight values of 52% and 72% to 77% ($\underline{X}^2 = 7.4$, $\underline{P} < 0.5$) and 91% ($\underline{X}^2 = 0.76$, $\underline{P} > 0.98$) when each area was flown twice during 1978 and 1979, respectively. A third flight for each area identified 85% and 96% of the leks for the 2 years (1978: $\underline{X}^2 = 3.6$, $\underline{P} < 0.75$; 1979: $\underline{X}^2 = 0.25$, $\underline{P} > 0.99$).

These data indicate that aerial surveys based upon a single flight dramatically underestimate the number of leks on an area. The number of leks on an area is dynamic. New leks appear and activities at some lek sites cease throughout each spring. In addition, a decline in number of males at "dominant" leks and subsequent appearance of smaller "satellite" leks (Hamerstrom and Hamerstrom 1973) means the number of leks increase on an area as the season progresses. Detection of these satellite, sometimes ephemeral, leks is essential to obtaining reliable indices to relative population size (Cannon 1980). Data from multiple flights increased the number of leks observed during aerial surveys. A summary of 3 flights was required to achieve statistical indifference

Table 1. Comparison of number of leks observed by aerial survey with known number of leks on greater prairie chicken study areas.

Study area	Best single flight 1978	Best single flight 1979	Best 2 flights 1978	Best 2 flights 1979	Total 3 flights 1978	Total 3 flights 1979	# leks known to exist on area 1978	# leks known to exist on area 1979
1	7	9	10	11	11	11	11	11
2	8	5	13	7	17	9	19	9
3	5	2	6	3	7	3	9	4
4	0	0	0	0	0	0	1	0
5	3	4	6	4	6	4	7	4
6	5	-	7	-	7	-	7	-
7	11	12	15	15	17	15	22	15
8	-	10	-	14	-	15	-	15
Percentage of total leks observed	52	72	77	91	85	96		

between aerial surveys and ground census data.

Ground counts are dependant upon locating prairie chickens visually or by auditory triangulation. Inclement weather (especially mud after rains) plus rolling terrain, lapses in vocalizations, and background noise hamper locating leks. Weather conditions (rain and winds) also necessitated the rescheduling of many aerial surveys. Strong winds increased air turbulence, affected relative ground speed of the aircraft, and created difficulty in maintaining transect spacing. Since rain and winds also reduce prairie chicken attendance at leks (Edminster 1954), information gathered on such days would be marginal.

Derdeyn (1974) attempted to count prairie chickens by aerial survey in the fall, but birds were dispersed and difficult to flush from dense cover, thus reducing success of the surveys. Prairie chickens did flush from leks during aerial surveys early in the spring, but tended to not flush as the season progressed. However, in this study, birds on leks were easily seen when they did not flush due to the shorter vegetation of spring.

MANAGEMENT IMPLICATIONS

Biologists have traditionally found it difficult to count prairie chickens during aerial survey (Eng 1955, Derdeyn 1975). Leks, however, are more visible and provide reliable indices to prairie chicken population trends over large areas (Cannon 1980). Aerial survey appears to provide a rapid and efficient method of counting leks on areas, especially where access is difficult. Increased rate of coverage and reduced manpower requirement enhances the cost-effectiveness of the aerial surveys. Multiple flights (preferably

3/area) appear essential to monitor ephemeral characteristics of "satellite" leks. Multiple observations are recommended during either aerial surveys or ground counts to reduce similar biases encountered due to subtle weather conditions and behavior changes of breeding prairie chickens.

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CHAPTER IV

EVALUATION OF HABITATS OF GREATER PRAIRIE CHICKEN POPULATIONS IN OKLAHOMA WITH EMPHASIS ON LANDSAT APPLICATIONS

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Abstract: Landsat satellite information and ground-truth data were obtained for seven 16 section areas in northeastern Oklahoma. Six to 14 resource classes were identified per area on the basis of rangeland quality, row-crop type, timber type, bare soil, and water. An independant assessment (Level 1) verified 85.6 ± 7.5% accuracy at the 90% confidence interval for the overall identification. These data were interpreted relative to population levels (as indexed by lek density) of greater prairie chickens (*Tympanuchus cupido pinnatus*) on those areas. Significant relationships were not found between

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vegetative parameters gathered on the ground and estimates of prairie chicken lek densities. Lek densities of prairie chickens were positively correlated (*r* = 0.68, *P* = 0.09) with percentage rangeland area and negatively correlated (*r* = -0.64, *P* = 0.12) with the percentage of tilled cropland area. Landsat imagery can provide useful habitat information at a cost-effective rate.

The numbers of greater prairie chicken (*Tympanuchus cupido pinnatus*) in Oklahoma, while stable in some areas, have decreased in portions of their range. The current range is fragmented and prairie chickens are distributed over a relatively large area (Martin and Knopf, ms). Habitats utilized by prairie chickens have been evaluated through various approaches including intensive field examinations and quantification from aerial photographs (Evans and Gilbert 1969, Arthaud 1971, Drobney and Sparrowe 1977). However, none of these techniques is cost or time-effective considering the scattered distribution and low density of prairie chicken populations in Oklahoma.

Landsat digital data provide information for relatively large areas that can be rapidly evaluated through computer assisted processing. Landsat imagery information has been applied to many wildlife programs recently (Brabander 1974, Frye et al. 1979, Katibah and Graves 1979, Parker 1979). This project compared the lek densities of greater prairie chickens with land-use data derived from both traditional ground and the newer, remote source, Landsat.

We thank P. A. Vohs and J. A. Bissonette for their assistance in the coordination of the project. Digital processing and technical assistance were provided by the U. S. Geological Survey's EROS Data Center (USGS-EDC) in Sioux Falls, South Dakota. We thank L. R. Pettinger, EROS Data Center, for his assistance with the digital analysis of Landsat data. This paper is a contribution from Federal Aid in Wildlife Restoration; P. R. Project Oklahoma W-125-R, Oklahoma Department of Wildlife Conservation, and Oklahoma State University Environmental Institute, cooperating.

STUDY AREAS

The current range of the greater prairie chicken in Oklahoma (Martin and Knopf, ms) lies within Duck and Fletcher's (1943) Tallgrass Prairie and Postoak-Blackjack Forest game types and Bailey's (1976) Oak-Hickory Bluestem Parkland and Oak and Bluestem Parkland sections of the Prairie Parkland province.

Seven 16-section (4,144 ha) study areas were selected for investigation based upon estimates of population densities of prairie chickens. Of these sites, 2 areas were estimated to have low population numbers, 3 with high numbers and 2 were intermediate. The 7 study areas were located in Craig, Mayes, Noble, Nowata, Osage, and Wagoner counties. The density of displaying males was determined for each study area using both ground counts and aerial survey (Martin and Knopf, ms).

METHODS

Prairie Chicken Estimates

Prairie chickens were located on leks by auditory triangulation during the first 3 h of daylight in spring 1978 and 1979. The location of each lek was recorded on a topographical map of the area (Hamerstrom and Hamerstrom 1973). These ground surveys continued throughout the breeding season (until mid-May) except on dates of aerial survey.

Ground data on prairie chicken leks were supplemented by information from aerial surveys. Aerial surveys began in early March, 30 min after sunrise and required approximately an hour to cover an area. Each area was flown 3 times per season with the second flight occurring during the anticipated peak of lek activity in April.

Vegetation Description

Vegetation was characterized using line-interception methods (Canfield 1941). Percentage coverage of grass, brush, and open ground (bare soil or litter) were determined from measurements made along 32, 20-m transects. The transects were randomly located within the central 4 sections (1,036 ha) of each 16 section (4,144 ha) study area. The frequency of occurrance for grass, brush, and open ground was calculated from 2-m intervals along each transect.

An index of residual cover was obtained from visual-obstruction measurements on a density pole (Robel et al. 1970) at 2-m intervals along each transect. Variability in residual cover was calculated from the visual obstruction measurements. Line-transect data was collected in early spring before green-up each year to minimize the effect of new growth on vegetation measurements.

Remotely-sensed Data

Land-use evaluations were made from data collected by the U. S. Geological Survey's EROS Data Center (USGS-EDC) in Sioux Falls, South Dakota, using Landsat imagery. Computer compatible tapes (CCT's) of two Landsat scenes were required for coverage of all the study areas. Digital analysis of study areas in Craig, Nowata, and Osage counties was made from a Landsat scene (Path 29, Row 34) dated 23 September 1978. A Landsat scene (Path 29, Row 35) dated 2 October 1978 included study areas in Mayes, Noble, and Wagoner counties. Fall dates were selected to facilitate discrimination of agricultural row crops. The specific imagery dates were selected from available scenes of suitable quality for analysis.

Color-infrared aerial photographs (1:120,000) acquired by the National Aeronautics and Space Administration (NASA) 23 February 1973 and 14 July 1977 were used to aid in locating each study area within the Landsat scene. Topographical maps (1:24,000) were used to record detailed land cover patterns (e.g., grazing intensity, crop type) on each study area. Vegetation data from line-transects were used in conjunction with the topographic maps in the training phase of the digital classification.

Information from each Landsat scene was analyzed separately due to the differences in imagery dates. Differences in dates, sun angle, cloud cover, and soil moisture prevented co-analysis of the two tapes. Areas in Craig, Nowata, and Osage counties were analyzed separately from those in Mayes, Noble, and Wagoner counties. Each study area was centered within a block (120 lines X 170 samples) of picture elements (pixels) to facilitate digital analysis. Landsat digital data were analyzed using an interactive analysis procedure (Rhode 1978) on the Interactive Digital Imagery Manipulation System (IDIMS) at the USGS-EDC. A stratified sampling procedure (Fleming et al. 1975) selected training areas within each block of pixels. Training areas included representative samples of the various resource classes identifiable from ground-truth data (field investigation). Training areas for the northern counties (23 September 1978) composed 16.0% (13,050 pixels) of the 4 study areas. Training areas for the southern tape (2 October 1978) composed 33.3% (15,000 pixels) of the remaining 3 study areas.

An unsupervised clustering algorithm (ISOCLS) grouped training area pixels into homogeneous groups and generated a statistics file (Rhode 1978, Pettinger 1979, Rhode et al. 1979). Spectral clusters generated by the clustering algorithm (ISOCLS) were evaluated through the use of a video display screen. Single clusters and/or groups of clusters were color coded to facilitate pattern recognition and comparison with annotated aerial photographs. Cluster groups were assigned to resource classes based on ground-truth data. The final set of spectral clusters and corresponding training statistics for each rangeland type were used to classify the remainder of each block of pixels. The training statistics file was used by a maximum-likelihood classification algorithm (CLASFY) to create a 1-band classified image of each study area (Pettinger 1979, Rhode et al. 1979).

The first unsupervised clustering (ISOCLS) of training data for the northern areas generated 19 clusters and resulted in considerable spectral overlap based on a comparison with ground-truthing. Confusion within resource classes of agricultural types was experienced as well as a lack of definition between degrees of residual cover in rangeland classifications. The clustering algorithm (ISOCLS) parameters were modified and the classification repeated when known differences in vegetative cover were not detected (Table 1).

The second unsupervised clustering resulted in 35 clusters and represented a better classification when compared with ground-truthing.

Table 1. ISOCLS algorithm parameters specified for the first and second clustering of training area digital data and number of clusters generated. Northern counties include study areas in Craig, Nowata, and Osage counties. Southern counties include Mayes, Noble, and Wagoner counties.

Parameter	ISOCLS nomenclature	Normal range	Northern counties Specified values Trial 1	Northern counties Specified values Trial 2	Southern counties Specified values Trial 1
Maximum no. of iterations	ISTOP	15-30	20	25	25
Minimum no. of pixels/cluster	NMIN	15-30	25	15	15
Minimum combining distance of Landsat relative radiance values	DLMIN	2.5-4.0	3.0	3.2	3.2
Maximum standard deviation of Landsat relative radiance values	STDMAX	1.0-3.0	2.5	2.0	2.0
Maximum no. clusters	MAXCLS	30-60	50	50	50
No. clusters generated			19	35	50

The clustering algorithm (ISOCLS) parameters used in the second unsupervised clustering were applied to the training data for the southern tape and generated 50 clusters. Application of a maximum-likelihood classification (CLASFY) to the 7 study areas (120 X 170 pixel blocks) revealed additional confusion in the identification of rangeland and agriculture resource classes presumably as a result of variations in soil type and vegetation not included in the training areas. Due to constraints in time for machine processing, the selection of additional training areas and subsequent clustering were not performed.

A 16 section (4,144 ha) digital mask was applied to each classified block of pixels to isolate the actual study area. The number of pixels in each land-use class were recorded as percentages. Line-transect and Landsat data were compared with lek densities of prairie chickens on each study area (Martin and Knopf, ms) using simple statistical techniques.

In order to assess the accuracy of the overall classification, 15 clusters of 16 pixels (arranged 4 lines X 4 samples) in size were randomly selected from a stratified sample of resource classes according to frequency of occurrance of each on two study areas. Field investigations were conducted to locate each individual pixel sampling unit (PSU) using modified surveying techniques. PSU's were plotted from locations marked on topographic maps (1:24,000) without prior knowledge of the classification of land-use for the pixel. The sample size was allocated to determine overall accuracy of the classification and not the accuracy of any one resource class.

RESULTS

Line-intercept data were compared with lek densities of greater prairie chickens for 1978 (Table 2). The limited occurrance of brush and open ground in the transects in 1978 precipitated a change in the methodology to delete the percentage coverage and frequency of vegetative components in rangeland. Visual-obstruction measurements with a density pole provided an index of residual cover in 1978 and 1979 (Table 3). Analysis of the information for simple linear relationships failed to reveal any significant correlation between vegetative parameters and lek densities (Table 4).

The final classification resulted in 12 land-use classes on the northern areas (Table 5) and 6 land-use classes on the southern areas (Table 6). Land-use data were combined from the two tapes by grouping similar categories of land-use. All rangeland classes were combined because no distinct separation in quality was in common between the classifications. Agricultural classes were combined with bare soil because of the inability to distinguish harvested row crops from tilled ground in the tape of the southern counties. Timber classes were grouped due to their limited occurrance and value to prairie chickens.

Lek densities were found to be positively correlated with percentage rangeland area (r = 0.68, P = 0.09) and negatively correlated with percentage tilled cropland area (r = -0.64, P = 0.12), timber (r = -0.59, P = 0.17) and water (r = -0.71, P = 0.07).

DISCUSSION

Landsat imagery only recently has been applied to resource and wildlife related problems (Colwell et al. 1978, Adams 1979, Frye et al.

Table 2. Comparison of lek densities with vegetative parameters from line-transects for 1978. Rangeland descriptors were derived from 32 20-m transects on each area.

Study area	Leks/km^2	Rangeland percentage			Rangeland frequency		
		Grass	Brush	Open	Grass	Brush	Open
1	14	99.1	0.9	0.0	1.00	0.04	0.00
2	19	99.6	0.0	0.3	0.99	0.00	0.00
3	9	97.5	0.0	0.3	0.99	0.00	0.03
4	1	99.1	0.9	0.0	0.99	0.01	0.00
5	7	99.8	0.2	0.0	1.00	0.02	0.00
6	7	100.0	0.0	0.0	1.00	0.00	0.00
7	22	99.5	0.0	0.5	1.00	0.00	0.02

Table 3. Comparison of lek densities with residual cover parameters from line-transects for 1978 and 1979. Descriptors were derived from 32 20-m transects on each area.

Study area	1978			1979		
	Leks/km^2	Index	Variability	Leks/km^2	Index	Variability
1	14	16.89	71.94	11	8.09	34.69
2	19	9.67	57.94	9	4.60	22.81
3	9	6.31	26.37	4	8.16	35.64
4	1	5.14	35.63	4	11.70	37.39
5	7	15.09	82.95	4	11.70	37.39
6	7	11.02	34.77	-	-	-
7	22	5.52	26.83	15	4.25	17.12
8	-	-	-	15	5.08	21.19

Table 4. Simple correlation coefficients and probability levels for lek density and vegetative parameters.

Parameter	Correlation coefficient	P > r
1978		
Grass (%)	0.13	0.77
Brush (%)	- 0.41	0.37
Open (%)	0.12	0.80
Grass frequency	0.38	0.40
Brush frequency	- 0.11	0.81
Open frequency	0.39	0.39
Residual cover	0.03	0.95
Residual cover variability	0.00	0.99
1979		
Residual cover	- 0.17	0.71
Residual cover variability	- 0.14	0.76

Table 5. Landsat classification of northern study areas in Craig, Nowata, and Osage counties.

Landsat classes	Area 2 No. pixels	Area 2 Percentage area	Area 3 No. pixels	Area 3 Percentage area	Area 7 No. pixels	Area 7 Percentage area	Area 8 No. pixels	Area 8 Percentage area
Rangeland								
very low cover	3,393	38.0	1,316	14.0	962	10.6	1,090	12.0
low cover	927	10.4	2,403	25.5	4,640	51.2	4,301	47.5
moderate cover	3,856	43.2	4,264	45.2	2,884	31.8	2,458	27.2
high cover	268	3.0	549	5.8	161	1.8	159	1.8
weedy	57	0.6	328	3.5	266	2.9	354	3.9
Timber								
postoak-blackjack	33	0.4	61	0.6	5	0.1	387	4.3
riparian	95	1.1	298	3.2	22	0.2	0	0.0
evergreen	-	-	10	0.1	-	-	-	-

Table 5. (Continued)

Landsat classes	Area 2		Area 3		Area 7		Area 8	
	No. pixels	Percentage area	No. pixels	Percentage area	No. pixels	Percentage area	No. pixels	Percentage area
Agriculture								
bare soil	158	1.8	193	2.0	69	0.8	224	2.5
sudan	43	0.5	0	0.0	5	0.1	22	0.2
sorghum	101	1.1	1	0.1	22	0.2	49	0.5
Water	1	0.1	3	0.1	12	0.1	4	0.1
Total	8,932		9,426		9,055		9,048	

Table 6. Landsat classification of southern study areas in Mayes, Noble, and Wagoner counties.

Landsat classes	Area 1		Area 4		Area 5	
	No. pixels	Percentage area	No. pixels	Percentage area	No. pixels	Percentage area
Rangeland						
low cover	6,140	68.1	3,192	34.8	3,528	40.4
high cover	1,382	15.3	3,162	34.5	3,813	43.7
Timber						
deciduous	451	5.0	485	5.3	525	6.0
evergreen	0	0.0	31	0.3	64	0.7
Agriculture	1,027	11.4	2,195	24.0	724	8.3
Water	19	0.2	98	1.1	76	0.9
Total	9,019		9,163		8,730	

1979, Katibah and Graves 1979). The limited application of Landsat imagery in the past is a result of limited access to machine processing systems. The results of this study illustrate the application of Landsat imagery in analysis of terrestrial habitats.

Landsat digital analysis detected 2-4 levels of grazing intensity in rangeland, 3 types of wooded vegetation and at least 2 distinct types of agricultural row crops. Adequate ground-truthing is essential to detect differences between these resource classes. Geometrically correlating the ground-truth data with the classified scenes was difficult but field patterns of agriculture, and grazing intensities along fences provided detail to locate most ground-truth data. Future analyses of expansive rangeland tracts to quantify habitat quality should include geometric correction (Pettinger 1979). Landsat data geometrically corrected to overlay standardized maps will insure accurate correlation of ground-truth data with spectral clusters and greatly increase the discrimination capabilities of the machine processing system.

A single Landsat data set can provide only limited information for some land-use practices within an area. The single date coverage generated land-use classes approximating ground-truth data on each area. An assessment of the overall accuracy of the classification from one Landsat scene (strata) was made independently by personnel of the USGS-EDC. Overall accuracy was determined by this investigation to be 85.6 ± 7.5% at the 90% confidence interval for the grouped resource classes used in the comparisons with lek densities.

Identification of crop types using Landsat data requires classification during seasons of the year when spectral reflectance is most diverse. Generalized resource classes were used because the differences in dates between the individual computer-compatible tapes of the areas introduced additional processing variations. A knowledge of predominant species composition will aid in separation of important crops by date.

The evaluation of rangeland conditions should be conducted during the period when a particular habitat characteristic is critical to chicken survival. However, the greatest variation in spectral reflectance among rangeland classes can be detected in early spring as green-up is first initiated. At this time areas of low residual cover would appear as vegètation in vigorous growth, whereas areas of high residual cover would continue to appear as dormant vegetation due to rank material occluding the new growth. Subjective evaluations of the continuum can be made based on ground-truth criteria.

Following analysis of the land-use data we observed that lek densities are not well explained by any one particular parameter, either vegetative components or land-use criteria. Areas that approached limiting factor levels of prairie chicken habitat in terms of vegetative components were compensated by optimum land-use relationships and vice-versa. An evaluation of these relationships can be made by multiple regression techniques, however, the data from each area must be comparable with the others. Comparisons between the 2 resource classifications were difficult because of slight differences in grouping criteria. For example, the very low, low, moderate, and high residual cover classes of the northern area tape (Table 5) can not be comparably divided to fit the criteria of the low and high residual cover classes of rangeland in the tape of the southern areas (Table 6).

Accurate classification of all land-use classes would have required multi-seasonal Landsat coverage of the study areas; an expense considered excessive for this study.

Management attempts for greater prairie chickens should recognize the need to maintain grasslands of suitable quantity and quality (Christisen 1969). Declines in the population numbers of prairie chickens have been attributed to loss of rangeland (Hamerstrom et al. 1957, Yeatter 1963). Edminster (1954) describes the percentage area of grassland suitable for greater prairie chickens as 60-80% with birds marginally tolerating areas containing as little as 33-40% in several hundred acre blocks within 5,000-10,000 acres of contiguous habitable range. Landsat digital analysis can detect habitat quality parameters to which prairie chickens are sensitive and can monitor changes on a seasonal basis. The ability to monitor land-use on specific areas provides the manager the ability to prescribe changes within occupied range and analyze adjacent areas for potential of restoration attempts (Arthaud 1971, Westemeier 1971, Hamerstrom and Hamerstrom 1973). Landsat imagery can provide useful habitat information at a cost-effective rate. The analysis (machine processing and CCT's) cost 2.3¢ per hectare excluding the expense in collection of ground-truth data.

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APPENDIX

LEGAL DESCRIPTIONS OF THE STUDY AREAS

Table 1. Legal descriptions of the study areas.

Area	County	Location
1	Noble	S 35, 36, T 23 N, R 1 E S 31, 32, T 23 N, R 2 E S 1, 2, 11-14, T 22 N, R 1 E S 5-8, 17, 18, T 22 N, R 2 E
2	Osage	S 10-15, 22-27, T 28 N, R 6 E S 7, 18, 19, 30, T 28 N, R 7 E
3	Osage	S 36, T 28 N, R 8 E S 29-31, T 28 N, R 9 E S 1, 12, 13, T 27 N, R 8 E S 4-9, 16-18, T 27 N, R 9 E
4	Wagoner	S 15-22, 27-34, T 18 N, R 18 E
5	Mayes	S 35, 36, T 23 N, R 19 E S 31, 32, T 23 N, R 20 E S 1, 2, 11-14, T 22 N, R 19 E S 5-8, 17, 18, T 22 N, R 20 E
6	Nowata	S 34-36, T 25 N, R 14 E S 31, T 25 N, R 15 E
	Rogers	S 1-3, 10-15, T 24 N, R 14 E S 6, 7, 18, T 24 N, R 15 E
7	Craig	S 2-5, 8-11, 14-17, 20-23, T 26 N, R 18 E
8	Nowata	S 13-15, 22-27, 34-36, T 28 N, R 14 E S 18, 19, 30, 31, T 28 N, R 15 E

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