4483

AVIAN ASSEMBLAGE AND ABUNDANCE ON COLORADO TALLGRASS PRAIRIE AND ADJACENT GRASSLANDS

by

CARY T. RICHARDSON

Report submitted to the

City of Boulder Open Space Department

April 1999

AVIAN ASSEMBLAGE AND ABUNDANCE ON COLORADO TALLGRASS PRAIRIE AND ADJACENT GRASSLANDS

by

CARY T. RICHARDSON

Report submitted to the

City of Boulder Open Space Department

April 1999

ACKNOWLEDGMENTS

I would like to thank my advisor in the department of E. P. O. Biology, Dr. Alex Cruz, and the other members of my thesis committee, Dr. David Armstrong, Dr. Carl Bock, and Dr. Carol Wessman, for their guidance and support. I also sincerely appreciate the assistance of Dr. Michael Grant, Dr. Sally Susnowitz, William Merkle, Nan Lederer, Tim Hogan, Lynn Riedell, and Sean Metrick. This project received financial support from the City of Boulder Open Space Department and Boulder County Nature Association.

CONTENTS

TABLES

Table

FIGURES

Figure

INTRODUCTION

As a group, grassland birds have suffered steeper, more consistent, and geographically more widespread declines than any other ecological guild in North America (Askins 1993). In particular, populations of birds dependent on tallgrass prairie have declined significantly due to overwhelming prairie fragmentation (Knopf 1996). The collective decline of grassland bird species points to major landscape and ecosystem level changes that warrant immediate ecological inquiry (Steinaur and Collins 1996).

Grasslands are considered to be North America's most endangered ecosystem (Samson and Knopf 1994). The tallgrass prairie, which in extent has declined by 82 to 99 percent since 1830 due to agricultural development, has suffered the greatest disaster of any ecosystem on the continent (Flores 1996). Most tallgrass habitats in Colorado have been destroyed by urban development, agricultural cultivation, or overgrazing (Bock et al. 1995).

It has been estimated that as little as 4% of North America's pre-European settlement tallgrass prairie remains (Samson and Knopf 1994). Large tracts of tallgrass prairie can still be found in the Flint Hills of eastern Kansas and northeastern Oklahoma. These areas have rocky soils and or steep terrain making them unsuitable for agricultural cultivation. According to Steinaur and Collins (1996), the remainder of the historical range of tallgrass prairie includes only small, scattered fragments embedded in a mosaic of other habitats. This fragmentation results in increased edge effects, which include the heightened likelihood of invasion by exotic species, low genetic diversity in local populations, and increased extinction rates. Isolation of the remaining patches decreases the potential for gene flow among remnants and also decreases the recolonization potential for locally extinct species from neighboring remnants (Steinaur and Collins 1996).

Tallgrass prairie was once a common habitat type on the Colorado piedmont. Historical records from early botanists describe tallgrass prairie along the entire length of the Front Range including the foothills near Boulder (Vestel 1914, James 1930, Branson et al. 1965). As early as 1909, it was observed that much of Boulder County's grasslands had already been transformed by irrigation to cultivated fields and that non-native tree and shrubs were present in irrigated areas (Henderson 1909).

The City of Boulder Open Space (CBOS) Department acquired the majority of Boulder's remaining tallgrass prairie in the 1970's (City of Boulder Open Space and Colorado Natural Areas Program 1986). In the 1980's the Colorado Natural Areas Program (CNAP) supported the systematic inventory of tallgrass prairie habitat in Boulder County and determined that the City of Boulder's tallgrass parcels are the largest and highest quality remnants in Colorado (CBOS and CNAP 1986). These remnant patches, the Colorado Tallgrass Prairie, were designated a state natural area in 1984 (CBOS and CNAP 1986).

The Colorado Tallgrass Prairie is located immediately south of Boulder (portions of sec. 10,15,16, T1S, R70W) and includes eight parcels, which when combined cover 108.9 hectares (269 acres). Patches range in size from approximately 4 to 100 acres (CBOS and CNAP 1986). Remnant species in the Colorado Tallgrass Prairie are thought to include most of the plant species components necessary to be restored to a true tallgrass prairie community.

Management Objectives

The objectives for resource management of the Colorado Tallgrass Prairie include the following: to restore, conserve, and perpetuate the native flora and fauna to approximate pre-settlement conditions; to maintain the natural ecological processes in the tallgrass communities; to encourage educational and interpretive use of tallgrass relicts; to encourage the use of the natural area for scientific research consistent with the basic purpose of the natural area (CBOS and CNAP 1986).

However, particular adaptive management and conservation goals for tallgrass prairie are generally unclear because much of North America's tallgrass prairie was extirpated prior to extensive ecological study (Steinaur and Collins 1996). Lack of knowledge regarding pre-European settlement vegetation composition (Clements 1936), the fire frequency and season (Howe 1994), and the extent of grazing by large herbivores (Bamforth 1987), impedes the potential for restoration to pre-European settlement conditions. For restoration efforts to be effective it is not only important to have clear goals but it is also important to understand the current status of the community to be restored. This includes a detailed knowledge of the flora and fauna that are present in the area.

Previous Research

Few studies have documented avian use of the Colorado Tallgrass Prairie (City of Boulder Open Space, Colorado Natural Areas Program 1986). Thompson and Strauch (1986) conducted a three-year breeding bird study in 1984-1986 in which they determined breeding avifauna present on City of Boulder Open Space lands. Bobolinks and Grasshopper Sparrows (see Appendix A for scientific names) were observed nesting in the Colorado Tallgrass Prairie but little other species information is specific to these parcels.

Bock et al. (1995) censused 66 fixed-radius point counts located on CBOS grasslands, including counts on four of the eight tallgrass parcels. The remaining four parcels of the Colorado Tallgrass Prairie had not been previously surveyed for avian diversity or abundance. Bock et al. (1995) compared the relative abundances of birds in the Colorado Tallgrass Prairie with adjacent grassland habitats and "True Prairie" habitats across the Great Plains. This was done to determine if Colorado Tallgrass Prairie species assemblages more closely resembled birds in adjacent grassland habitats or those of the farther away, more contiguous "True Prairie" to the east (Bock et al. 1995). Their study considered the extent of grassland habitats and because of this, they only selected study sites that were surrounded by least 100 hectares of the same habitat type. Although focusing on different patch sizes, this research laid the foundation for questions particular to the smaller, remnant tallgrass patches examined in my research.

Objectives

The primary objectives of this study were to document avian assemblage and abundance within the Colorado Tallgrass Prairie parcels that met the following criteria: a) previously had not been surveyed for avian species; b) vegetation type and extent was sufficient to include a 100 m radius study site; c) tallgrass patches were proximate if not adjacent to mixed grass sites and non-native hay fields. Data collected within the tallgrass sites were compared with avian assemblage and abundance estimates of adjacent mixed-grass prairies and non-native hay fields. These comparisons allow me to infer if the Colorado Tallgrass Prairie patches are functioning as tiny, distinct ecosystems for birds.

This inference would be strongest if birds endemic to tallgrass prairie were found within the remnant patches. However, due to the recent origin of North American grasslands, there are very few endemic bird species and it is thought that none are completely confined to tallgrass prairie (Axelrod 1985, Zimmerman 1993, Bock et al. 1995). The Dickcissel (see Appendix A for scientific names) and Henslow's Sparrow are the only two avian species that are considered to be tallgrass-specific (Knopf 1996). Furthermore, Dickcissels are considered rare to very local species along the Front Range (Bailey and Neidrach 1965, Andrews and Righter 1992) while Henslow's Sparrows are considered accidental spring or fall migrants in Colorado and no records exist for this species in Boulder County (Andrews and Righter 1992). If avian species that are known to be closely associated with or specific to tallgrass prairie are found in higher abundance in the tallgrass patches than in the adjacent mixed grass and non-native hay fields during the breeding season, then it is assumed that some level of tallgrass ecosystem function exists.

Alternatively, the presence of numerous species more generally associated with tallgrass prairie in higher abundance in the remnant patches than in surrounding habitats may also indicate a functioning tallgrass ecosystem. If, however, the same avian assemblages are found in all the grassland habitats, then the remnant tallgrass patches are clearly not functioning as a distinct habitat type.

The secondary objective was to resolve a methodological question associated with avian relative abundance estimates in grassland habitats. Despite the fact that their utility in open lands has been questioned (Gibbons et al. 1996, Bibby et al 1992), point counts are the most commonly used method for measuring bird abundance in Boulder grasslands (Bock et al. 1995, Vierling 1997, Miller 1997). However, spot mapping is generally considered the most accurate method for measuring bird abundance in open habitats (Bibby et al. 1992)

Spot mapping (William 1936, Kendeigh 1944, Reynolds 1980), also known as territory mapping, is conducted during the breeding season when passerine birds announce their territories with conspicuous songs, displays, and periodic disputes with neighbors (Bibby et al. 1992). The spot mapping method is considered by some to be the standard against which other methods estimating relative abundance and density can be compared (Bibby et al. 1992). The mapping approach relies on locating all signs of territorial behavior and uses these signs to estimate the number of territories and the number of birds using each territory within the census area.

The modified method of spot mapping used in this study relied on observing the territorial behavior of birds within each defined study area (100 m radius). Due to the small size of each study site, it was unlikely that any bird territory was wholly within the exact boundaries of the area. Therefore, it was not the actual territory boundaries that were observed but the territorial behavior that was observed within each study site. A 50 m grid was placed on a map of each study site and transects were established to cover each site. Therefore this modified spot mapping can also be thought of as a sort of line transect technique, which is also generally considered to be more accurate than point counts in open areas that are relatively uniform in vegetation structure and composition (Bibby et al. 1992). For the purposes of this project, it was assumed that the modified spot mapping technique was the more reliable method, and it was used as the standard against which point count estimates were compared.

Variable circular-plot censusing, commonly referred to as point counts (Reynolds et al. 1980), is a method of counting birds that is widely used in the United States (Bibby et al. 1992). With some assumptions about the varying detectability of birds at different distances, point counts can be an efficient method for calculating bird abundance (Reynolds et al. 1980). The use of point counts has been tested and assessed rather extensively in a variety of habitat types (Dickson 1978, Reynolds et al. 1980, Bart and Schoultz 1984, DeSante 1986, Gutzwiller 1993, Barker et al. 1993, Whitman et al. 1997), but their accuracy has not been proven in grassland habitats. There is a need to test the accuracy of point counts in a variety of habitat types and for various species (Bednarz pers. comm. 1997, Bock pers. comm. 1997). This projects compares the extent of similarity between modified spot mapping and point counts to determine if positive or negative correlations exist.

Significance of Study

The information generated by this study can be used to assess management practices within and surrounding the tallgrass patches by determining if the patches are preferred nesting and or foraging habitat for grassland birds. Baseline data on species use of the area is essential to understanding the area's current level of ecosystem function. This baseline information will be critical for successful future restoration efforts. This information will also be valuable in the development of future Area Management Plans for the CBOS department and for the Colorado Tallgrass Prairie Management Plan, which is due for revision in the near future. Information gained may also help refine the use of various methods for estimating relative abundance of grassland birds in Boulder County and elsewhere.

METHODS

Study Area and Site Selection

Nine study sites were selected within three different grassland habitat types in Boulder County, Colorado. These habitat types included tallgrass prairie, mixed-grass prairie, and non-native hay fields. Study sites were located immediately south of Boulder, Colorado, in the South Boulder Creek valley and on Davidson Mesa (Figure 1). These sites range in elevation from approximately 1670 to 1740 m (5480 to 5700 feet). All sites were located to the east of South Boulder Creek. The study sites are on the Church, Van Vleet, Yunker, and Damyanovich properties that are owned and managed by the City of Boulder Open Space Department (CBOS). The management of all of the sites was similar in that winter/spring grazing is typical from November until mid-May. Hay fields are typically mowed between 4 and 25 July.

The Colorado Tallgrass Prairie patches are embedded in a mosaic of more extensive habitats, including irrigated hayfields and dry uplands with short and mid-stature grasses (Bock et al. 1995). The close proximity of these distinct habitat types allowed for all study sites to be located within a compact area, which limited the range of surrounding landscape variables. Sites ranged from 100 to 750 m from the nearest road. No established recreational trails were in or near the study sites. Public access was not prohibited, nor was it encouraged. Visitors must climb fences to enter the areas, so visitation was low in all sites.

The habitat classification by which study sites were selected was based upon research conducted on the CBOS lands that mapped vegetation habitats within the South Boulder Creek Valley and Davidson Mesa areas (Bunin 1985). The CBOS plant ecologist helped to establish representative habitat area; sites were randomly selected within the representative habitat areas. Other selection factors included topography and clear visibility from the center point to all areas of each study site.

Three study sites were selected within the Colorado Tallgrass Prairie Natural Area on parcels 1 (approximately 4 acres), 2 (approximately 8 acres), and a portion of 10 (approximately 100 acres) (Figure 1). Three additional sites were selected in nearby mixed-grass prairie and three in nearby non-native hay fields for a total of nine sites. Each study site included one fixed-radius circular census plot (100 m radius). Center points of neighboring sites were at least 250 m apart to avoid double counting individual birds (Bibby et al. 1992). Assistance was provided by a GIS specialist from the CBOS Department to determine where 100 m radius circles would fit within the chosen areas and to ensure that each circle center was 250 m apart. Care was also taken to avoid, as much as possible, overlap with existing research plots in order to maximize the amount of baseline data on grassland birds that this study produced.

The center of each study site was marked with a 1 m high flag. Additional flags were placed along the circumference of each circle at 0° from center (north), 45° (north-east), 90° (east), 135° (south-east), 180° (south), 225° (south-west), 270° (west), and 315° (north-west) from the center. These additional flags were used to assist in distance estimates and when walking transects.

Estimating bird abundance and species assemblage

I surveyed breeding season songbirds between 15 May and 15 July 1998, between sunrise and 5 hours after sunrise. To avoid time-of-day bias, the morning count period was divided into three different periods: early morning, mid morning, and late morning (Verner and Ritter 1986). Two counts were conducted during each of the three time periods at each site. The seventh count was done during a random morning period.

Each study site was visited no more than every third day to reduce disturbance impacts to breeding and foraging birds. Birds observed flying overhead were not recorded. For example, aerial foragers, such as swifts and swallows, and also raptors were not included. Only birds in the orders Passeriformes, Charadriiformes, Columbiformes, and Anseriformes were detected and included in counts. Data were only collected on mornings when wind was estimated to be less than 16 km per hour (10 mph) and precipitation was limited to very light rain.

Point Counts

I conducted seven point counts (Reynolds et al. 1980, Bibby et al. 1992) at each of the nine sites for a total of 63 counts. Fixed-radius (100 m) point counts were used with a 10-minute duration. Birds detected visually and or audibly and confirmed to be within the boundaries of the study site were recorded. Data collected included species, sex, estimated distance from center and direction from center, and whether the bird had adult or immature plumage.

Spot Mapping

After the 10-minute point count was completed, modified spot mapping using transects was done at each site. Point count data were collected first to avoid flushing or disturbing birds by walking transects. Seven maps were created for each of the nine sites for a total of 63 spot maps. Territory mapping (William 1936, Kendeigh 1944, Bibby et al. 1992) and line transects (Bibby et al. 1992) were combined for this spot mapping technique (Reynolds et al. 1980) in order to accommodate the small plot size and to allow for a comparison of abundance estimate generating methods.

A 50 m grid was placed over an aerial photo of the study site to establish mapping units. This grid created three transects, 50m apart, which divided each study site. These transects ran from 0° to 180°, 45° to 135°, 225° to 315° along the circumference of each study site (Figure 2). Transects were walked in an 'S' pattern, with the starting point alternating between 45°, 135°, 225°, and 315°. Birds were recorded that could be confirmed to be within the study site boundaries. Upon flushing or otherwise detecting a bird, the location of the bird, its species, sex, and whether it had adult or immature plumage were recorded on a data sheet. These data sheets included a digital orthographic photo upon which the bird location information was recorded (Figure 2).

Vegetation Measures

Vegetation structural measurements were based on Wiens (1969,1973) and Rotenberry and Wiens (1980). Four 2 m square plots were selected randomly in each of the nine sites for a total of 36 vegetation plots. Vegetation surveys were conducted between 15 July and 15 August. One plot was placed within each quarter of each circular study site. Within each plot, vegetation density, structural heterogeneity, species composition, and estimated percent cover were recorded.

For density, a 10 cm wide board marked with a checkerboard of 1x1 cm squares was placed into the vegetation vertically (Wiens 1969 and 1973, Rotenberry and Wiens 1980). From a distance of approximately 5 m away, I estimated the height of the board where 90 percent of the squares were concealed by vegetation (Bibby et al. 1992). Density measures were taken at each of the four corners of the 36 vegetation plots and were averaged by site and habitat type.

Vegetation structural heterogeneity was measured based on the height of the vegetation at each of the four corners of each of the 2 m square quadrats. Structural heterogeneity was then calculated using the following equation:

$$\text{Heterogeneity index} = \frac{\Sigma\,(max - min)}{\Sigma x}$$

(Wiens 1969 and 1973, Rotenberry and Wiens 1980) where *max* is the maximum height of the vegetation at the four corners of a quadrat, *min* is the minimum height of vegetation at the quadrat corners, and x is the mean height of the vegetation in a quadrat. Values were averaged by site to give an overall structural heterogeneity measure that was compared between sites.

Plant species composition and estimated percent cover were recorded at each of the 36 vegetation plots. Species readily identifiable in the field were recorded with estimates of their percent cover. The Braun-Blanquet cover abundance scale (Mueller-Dombois and Ellenberg 1974) was used to estimate species percent cover.

All species whose cover was estimated to be 1 percent or greater were recorded. For those species that could not be identified in the field, specimens were collected and percent cover was estimated. Unidentified specimens were later identified by experts in local grassland flora.

Statistical Analyses

Nested ANOVA analyses (Zar 1996, Cody and Smith 1997) were done to test if detection levels by species were the same among habitat types for the two different methods, spot mapping and point counts. The use of nested analyses controlled for variation in observations of species between counts, among sites, and within a habitat type. Percent relative abundance was also calculated for abundance estimates generated by both methods for all species within each habitat (Table).

Non-parametric analogs of simple one-way analyses by ranks (Kruskal-Wallis tests (Zar 1996, Cody and Smith 1997)) were done on species detection data from both the spot mapping and point count techniques to test if species observations by habitat were equal. Results of the nested ANOVA analyses were compared to those of the Kruskal-Wallis tests to determine if all necessary assumptions were met for parametric analysis. If results were similar (both test results showed either a significant difference ($P=$ or < 0.05) for a given species or no significant difference ($P>0.05$)) then I concluded that all necessary assumptions were met (M. Grant pers. comm.). For cases in which the assumptions were not met, the more conservative, non-parametric (Kruskal-Wallis) test results were used. In all other cases, the more powerful parametric nested ANOVA results were used (M. Grant pers. comm.).

Although nest searching was not a method employed in this study, several nests were inadvertently located while conducting surveys. The most remarkable were two Dickcissel nests found within the Colorado Tallgrass Prairie (Figure 2). These nests were located in Russian-olive trees and contained 3 and 4 fully feathered young that appeared to fledge successfully. This marks the first breeding record for this species in Boulder County. One nest was collected (covered by City of Boulder Open Space permit) and deposited at the University of Colorado Museum.
Two Western Meadowlark nests were located during the course of research. One nest with four eggs was located within tallgrass site and the other nest had four young nestlings and was located on Davidson mesa between two mixed grass sites. A Vesper Sparrow nest with four eggs was also located on Davidson mesa on the periphery of one of the mixed grass sites. A Black-billed Magpie nest with six eggs was discovered between tallgrass sites in a Russian-olive tree. This nest was later abandoned for unknown reasons. Two Common Snipe nests with eggs were found outside of hay field sites. Finally, a Red-tailed Hawk nest with two nestlings was on the periphery of a hay field site in a large plains cottonwood tree along an irrigation ditch.

Table 2. Species detected by point counts within each habitat and the number of counts in which the species was observed within each habitat. Total number of possible observations =21.Those species considered breeding season residents are shown in bold. Species detected only by point counts are shown in italics.

TALLGRASS	# of counts observed	MIXED GRASS	**# of counts observed**	**HAY FIELDS**	**# of counts observed**
Common Snipe	1	Killdeer	1	**Common Snipe**	8
Black-billed Magpie	3	Mourning Dove	1	Common Nighthawk	1
Horned Lark	4	Eastern Kingbird	1	American Robin	2
American Robin	1	**Vesper Sparrow**	15	Vesper Sparrow	1
European Starling	2	Lark Bunting	2	Savannah Sparrow	2
Vesper Sparrow	5	**Grasshopper Sparrow**	17	**Grasshopper Sparrow**	3
Grasshopper Sparrow	20	Song Sparrow	2	Song Sparrow	1
Song Sparrow	2	**Western Meadowlark**	21	Dickcissel	1
Dickcissel	6			**Bobolink**	17
Bobolink	5			**Red-winged Blackbird**	21
Red-winged Blackbird	5			**Western Meadowlark**	12
Western Meadowlark	20			Common Grackle	1
Common Grackle	1				
Bullock's Oriole	1				

Table 4. Descriptive statistics for species observations per spot map or point count for each habitat type. Species observed once or more are listed. If a species was not detected by one of the methods, then it is indicated by a dash (-). The total number of observations per habitat type = 21.

HABITAT TYPE	SPECIES	MEAN, MAP	MEAN, PT. CT.	STD. DEV., MAP	STD. DEV., PT. CT.
Hay Field	Mallard	0.048	-	0.22	-
	Common Snipe	0.62	0.57	1.12	0.93
	Common Nighthawk	-	0.047	-	0.22
	American Robin	0.047	0.095	0.22	0.301
	Vesper Sparrow	-	0.095	-	0.301
	Savannah Sparrow	-	0.095	-	0.301
	Grasshopper Sparrow	-	0.14	-	0.36
	Song Sparrow	-	0.48	-	0.22
	Dickcissel	-	0.095	-	0.44
	Bobolink	2.62	2.81	2.96	2.44
	Red-winged Blackbird	2.86	3.048	2.89	2.085
	Western Meadowlark	0.19	0.76	0.61	0.83
	Common Grackle	0.095	0.048	0.301	0.22
Mixed Grass	Killdeer	-	0.048	-	0.22
	Mourning Dove	-	0.048	-	0.22
	Common Nighthawk	0.19	-	0.51	-
	Eastern Kingbird	-	0.048	-	0.22
	Horned Lark	0.048	-	0.22	-
	Vesper Sparrow	1.19	1.048	1.21	1.024
	Lark Bunting	1.95	0.33	8.95	1.32
	Grasshopper Sparrow	1.76	2.29	1.58	0.78
	Song Sparrow	-	0.095	-	0.301
	Western Meadowlark	1.95	2.24	1.47	1.22
Tallgrass	Common Snipe	0.048	0.048	0.22	0.22
	Black-billed Magpie	-	0.24	-	0.63
	Horned Lark	0.048	0.190	0.22	0.402
	American Robin	0.19	0.048	0.68	0.22
	European Starling	-	0.24	-	0.89
	Vesper Sparrow	0.048	0.24	0.22	0.44
	Grasshopper Sparrow	1.33	2.000	1.62	0.89
	Song Sparrow	-	0.095	-	0.301
	Dickcissel	0.52	0.76	1.37	1.34
	Bobolink	0.29	0.38	0.902	0.92
	Red-winged Blackbird	0.14	1.29	0.48	4.99
	Western Meadowlark	1.095	1.95	1.00	0.87
	Bullock's Oriole	0.14	0.048	0.48	0.22
	Common Grackle	0.095	0.048	0.301	0.22

Table 5. Results of nested ANOVA for point count generated abundance estimates. When assumptions were not met, non-parametric tests (Kruskal-Wallis) were used. These cases are indicated by 'non-parametric' by the species name. Cases in which the association of species and habitat type or species and site is significant (P>0.05) are indicated with an asterisk (*).

SPECIES	VARIANCE SOURCE	% OF TOTAL VARIANCE	F-VALUE	PROBABILITY
Killdeer	Habitat	0.00	1.00	0.42
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Common Snipe	Habitat	22.65	13.30	0.006*
	Site	0.00	0.81	0.81
	Error	77.35		
	Total	100.00		
Mourning Dove	Habitat	0.00	1.00	0.42
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Common Nighthawk	Habitat	0.00	1.00	0.42
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Eastern Kingbird	Habitat	0.00	1.00	0.42
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Black-billed Magpie	Habitat	11.27	25.00	0.001*
	Site	0.00	0.11	1.00
	Error	88.73		
	Total	100.00		
Horned Lark (non-parametric)	Habitat	10.71	4.71	0.013*
	Site	14.29		
	Error	75.00		
	Total	100.00		
American Robin	Habitat	0.00	0.60	0.58
	Site	11.11	1.88	0.10
	Error	88.89		
	Total	100.00		
European Starling	Habitat	0.00	1.00	0.42
	Site	7.84	1.60	0.17
	Error	92.16		
	Total	100.00		

Table 5. Continued

Vesper Sparrow (non-parametric)	Habitat	28.89	15.12	0.0001*
	Site	21.72		
	Error	49.39		
	Total	100.00		
Lark Bunting	Habitat	2.26	1.58	0.28
	Site	0.00	0.84	0.55
	Error	97.74		
	Total	100.00		
Savannah Sparrow	Habitat	0.00	1.00	0.42
	Site	16.67	2.40	0.04*
	Error	83.33		
	Total	100.00		
Grasshopper Sparrow	Habitat	71.58	39.80	0.0003*
	Site	1.72	1.45	0.21
	Error	26.69		
	Total	100.00		
Song Sparrow	Habitat	0.00	0.33	0.73
	Site	0.00	0.60	0.73
	Error	100.00		
	Total	100.00		
Dickcissel (non-parametric)	Habitat	14.25	5.66	0.006*
	Site	11.13		
	Error	74.62		
	Total	100.00		
Bobolink (non-parametric)	Habitat	39.63	34.91	0.0001*
	Site	32.53		
	Error	27.84		
	Total	100.00		
Red-winged Blackbird	Habitat	16.17	5.13	0.05*
	Site	0.00	0.98	0.45
	Error	83.84		
	Total	100.00		
Bullock's Oriole	Habitat	0.00	1.00	0.42
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Common Grackle	Habitat	0.00	0.50	0.63
	Site	0.00	1.00	0.44
	Error	100.00		
	Total	100.00		
Western Meadowlark	Habitat	34.44	7.51	0.023*
	Site	7.59	1.92	0.095
	Error	57.96		
	Total	100.00		

Table 6. Percent relative abundance of birds in three grassland habitats.

	TALLGRASS		MIXED GRASS		HAY FIELDS	
	Spot Mapping	Point Counts	Spot Mapping	Point Counts	Spot Mapping	Point Counts
Mallard	0	0	0	0	1.0	0
Killdeer	0	0	0	0.8	0	0
Common Snipe	1.2	.6	0	0	11.5	10
Mourning Dove			0	0.8	0	0
Common Nighthawk	0	0	2.7	0	0	0.8
Eastern Kingbird	0	0	0	0.8	0	0
Black-billed Magpie	0	3.1	0	0	0	0
Horned Lark	1.2	2.5	0.7	0	0	0
American Robin	4.8	0.6	0	0	1.0	1.7
European Starling	0	3.1	0	0	0	0
Vesper Sparrow	1.2	3.1	16.8	17.1	0	1.7
Lark Bunting	0	0	27.5	5.4	0	0
Savannah Sparrow	0	0	0	0	1.7	1.7
Grasshopper Sparrow	33.4	26.3	24.8	37.2	0	2.5
Song Sparrow	0	1.3	0	1.6	0	0.8
Dickcissel	13.1	10	0	0	0	1.7
Bobolink	7.1	5	0	0	23.1	11.7
Red-winged Blackbird	3.6	16.9	0	0	57.7	53
Western Meadowlark	27	25.6	27.5	36.4	2.9	13
Common Grackle	2.4	0.6	0	0	1.9	.8
Bullock's Oriole	3.6	0.6	0	0	0	0

Methods Correlations

The two methods, spot mapping and point counts, were compared using Spearman Correlation Coefficients. The total number of birds detected by spot mapping was correlated with the total number detected by point counts. This resulted in a significant positive correlation (Table 7) with 60% of the spot mapping variation was not explained by point count variation. Spearman Correlation Coefficients were also used to compare the total number of birds located by each method within each habitat type (Table 8). This test also revealed positive correlations between the methods in each of the three habitat types with 30% of spot mapping variation unexplained by the variation in point counts in tallgrass sites, 39% unexplained in mixed grass sites, and 66% unexplained in hay fields.

Species were then ranked by abundance within each habitat type and by each method (Table 9). The top three ranked species for each habitat were fairly similar between the two methods with some discrepancies. Spot mapping in tallgrass sites ranked Grasshopper Sparrows as the most abundant species detected followed by the Western Meadowlark and the Dickcissel. Point count estimates ranked the top two species the same but ranked the Red-winged Blackbird as the third most abundant species. In mixed grass sites, Lark Buntings and Western Meadowlarks tied for the most abundant species observed during spot mapping with the Grasshopper Sparrow second and Vesper Sparrow third. This differs from the ranks of species detected by point counts in that Grasshopper Sparrows ranked first with Western Meadowlarks second and Vesper Sparrows third. The high abundance rank of Lark Sparrows detected by spot mapping was most likely the result of an early season flock of greater than forty birds that flew in during one survey. In hay fields, spot mapping results ranked the Red-winged Blackbird as the most abundant species observed, Bobolink as the second most abundant and Common Snipes third. Point counts ranked the top two species the same but showed Western Meadowlarks as the third most abundant.

A third correlation was done for species ranks between the two methods (Table 10) and showed significantly positive relationships between the abundance estimates of the two methods. In tallgrass sites, 51% of the variation is unexplained by the two methods, 52% in mixed grass habitats, and 60% was not explained by the methods in hay fields. Correlations across habitats (Table 11) show significant ($P<0.05$) positive relationships for abundance estimates between tallgrass and hay fields for both spot mapping and point counts. There is not a significant correlation between estimates of mixed grass with tallgrass sites or hay fields.

Table 7. Means, standard deviations, Spearman correlation coefficient, and significance for the total number of observations of birds detected by spot maps and point counts, N=1448. Significant correlation (P>0.05) indicated by an asterisk (*).

METHOD	MEAN	STANDARD DEVIATION	SPEARMAN CORRELATION COEFFICIENT	SIGNIFICANCE
Spot Mapping	0.26	1.395	0.63	0.0001*
Point Counts	0.32	1.075		

Table 8. Means, standard deviations, Spearman correlation coefficient, and significance of the total number of birds detected within each habitat type by method, N=482. Significant correlations (P>0.05) indicated by an asterisk (*).

HABITAT	METHOD	MEAN	STANDARD DEVIATION	SPEARMAN CORRELATION COEFFICIENT	Significance
Hay Field	Spot Map	0.28	1.17	0.58	0.0001*
	Point Count	0.34	1.095		
Mixed Grass	Spot Map	0.31	2.0077	0.78	0.0001*
	Point Count	0.27	0.8001		
Tallgrass	Spot Map	0.18	0.66	0.55	0.0001*
	Point Count	0.34	1.28		

Table 10. Spearman Correlation Coefficients and significance of species ranks generated by spot mapping correlated with point counts within each habitat type. Significant correlations (P>0.05) are indicated with an asterisk (*).

	Hay Fields	Tallgrass	Mixed Grass
Spearman Correlation Coefficient	0.64	0.70	0.69
Significance	0.0019*	0.0004*	0.0006*

Table 11. Spearman Correlation Coeficients followed by significance of relative abundance estimates between habitats. Significant correlations are indicated by an asterisk (*).

	SPOT MAPPING		POINT COUNTS	
HABITAT	MIXED GRASS	HAY FIELD	MIXED GRASS	HAY FIELD
TALLGRASS	0.089	0.46	0.086	0.56
	0.701	0.038*	0.71	0.0088*
MIXED GRASS	1.00	-0.13	1.00	0.036
	0.00	0.56	0.00	0.88

Vegetation Measures

Vegetation species composition surveys identified 43 plant species within the twelve tallgrass plots (Table 12). Forty species were identified in mixed grass plots, and 27 were found in hay fields. Eight species covered at least fifty percent of at least one of vegetation plot in tallgrass sites. These species include *Agrostis gigantea, Andropogon gerardii, Asclepias incarnata, Asclepias speciosa, Carex nebrascensis, Panicum virgatum,* and *Rosa arkansana.* Ten species covered at least fifty percent of at least one of the vegetation plots in mixed grass sites. These species include *Andropyron smithii, Ambrosia psilostachya* variety *coronopifolia, Anisantha tectorum, Buchloe dactyloides, Dianthus armeria, Erigeron spp., Gutierrezia sarathrae, Pascopyrum smithii, Pterogonum alatum,* and *Sorghastrum avenceum.* Seven species covered at least fifty percent of at least one plot in hay field sites. These species include *Dactylis glomerata, Festuca pratensis, Phleum pratense, Plantago lanceolata, Scirpus lineatus, Spartina pectinata,* and *Trifolium pratense.* A complete list of species and their estimated percent cover can be found in Appendix B.

Vegetation structural measurements (Wiens 1969, 1973, Rotenberry and Wiens 1980, Bibby et al. 1992) of plant heights showed that hay fields (0.45) have the lowest heterogeneity index (Table 13). This suggests homogeneity of plant heights. Mixed grass sites had the highest heterogeneity index (1.017) suggesting heterogeneous plant heights. Tallgrass sites were slightly more heterogeneous than hay field sites (0.55) in terms of plant heights but they were still fairly uniform.

Average vegetation density (Wiens 1969, 1973, Rotenberry and Wiens 1980, Bibby et al. 1992) was lowest for the mixed grass sites (18.60 cm) and highest for the tallgrass sites (57.91 cm). The average density of hay field vegetation (47.20 cm) was not far below that of tallgrass sites (Table 13).

Table 12. Plant species located within each habitat. Bolded species names covered 50% or more of at least one of the twelve vegetation plots within the selected habitat. Species names follow Weber 1990.

TALLGRASS	MIXED GRASS	HAY FIELD
Agrostis gigantea	*Adenolium lewisii*	*Apocynuen cannabinum*
Ambrosia psilostachya, variety coronopifolia	***Agropyron smithii***	*Carex brevior*
Andropogon gerardii	*Alyssum alyssoidies*	*Carex lanuginosa*
Aretmisia ludaviciana	***Ambrosia psilostachya, variety coronopifolia***	*Carex nebrascensis*
Asclepias incarnata	*Andropogon gerardii*	*Carex scoparia*
Asclepias speciosa	***Anisantha tectorum***	*Cichorium intybus*
Bromopsis inermis	*Aristada purpurea*	*Convulvus arvensis*
Carex nebrascensis	*Artemisia frigida*	***Dactylis glomerata***
Carex praegracilis	*Artemisia ludavisiana*	*Dichanthelium oligosanthes, variety scribnerianum*
Cichorium intybus	*Bouteloua curtipendula*	*Eleocharis elliptica, variety compressa*
Cirsium arvense	***Buchloe dactyloides***	***Festuca pratensis***
Convulus arvensis	*Camelian microcarpa*	*Glyceria striata*
Critesion jubatum	*Carex brevior*	*Iris missouriensis*
Dactylis glomerata	*Cirsium arvense*	*Juncus longistylis*
Dalea candida oligophylla	*Convulvus arvensis*	*Lotus tenuis*
Elaegnus angustifolia	*Coryphantha spp.*	***Phleum pratense***
Elytrigia repens	*Dalea candida oligophylla*	***Plantago lanceolata***
Epilobium spp.	***Dianthus armeria***	*Plantago major*
Helianthus rigidus, variety subrhomboideus	***Erigeron spp.***	*Poa pratensis*
Heterotheca villosa	*Gastrolychnis drummondii*	*Prunella vulgaris*
Juncus longistylis	***Gutierrezia sarothrae***	*Rumex crispus*
Liatris punctata	*Heterotheca villosa*	*Scirpus americanus*
Neolepia campestre	*Koeleria macrantha*	***Scirpus lineatus***
Oligoneuron rigidum	*Lactuca serriola*	***Spartina pectinata***
Opuntia spp.	*Liatrus punctata*	***Trifolium pratense***
Panicum virgatum	*Oligoneuron rigidum*	*Triglochin maritimum*
Phacelia heterophlla	*Oligosporus pacificus*	*Typha spp.*
Phleum pratense	*Opuntia spp.*	
Phyla cuneifolia	***Pascopyrum smithii***	
Poa prantensis	*Phacelia heterophylla*	
Psoralea tenuiflora	*Poa compressa*	
Ratibida columnifera	*Psoralea tenuiflora*	
Rosa arkansana	***Pterogonum alatum***	
Scirpu americanus	*Silene antirrhina*	
Solidago canadensis	*Solidago mollis*	

Table 12. Continued

TALLGRASS	MIXED GRASS	HAY FIELD
Sorghastrum avenaceum	*Solidago nana*	
Spartina pectinata	***Sorghastrum avenaceum***	
Sporobolus heterolepis	*Stipa comata*	
Taraxacum officinale	*Verbascum thapsus*	
Thelasperma megapotamicum	*Yucca glauca*	
Tragopogon dubius		
Trifolium pratense		
Virgulus falcatus		

Table 13. Vegetation structure: heterogeneity and density by site and by habitat type (Wiens 1969,1973 and Rotenberry and Wiens 1980). Low heterogeneity values indicate homogeneity of vegetation heights and high values indicate heterogeneous vegetation heights.

	HETEROGENEITY INDEX	AVERAGE HETEROGENEITY	DENSITY	AVERAGE DENSITY(cm)
HAY 1	0.44		52.59	
HAY 2	0.19	0.45	58.00	47.20
HAY 3	0.72		31.00	
MIXED 1	1.16		8.22	
MIXED 2	0.90	1.017	6.94	18.60
MIXED 3	0.99		40.63	
TALL 1	0.63		33.84	
TALL 2	0.30	0.55	54.25	57.91
TALL 3	0.73		85.63	

DISCUSSION

Methodological Comparisons

Four correlation analyses were done to compare relative abundance estimates generated by spot mapping and point counts. These included correlations of the total number of birds detected by spot mapping and point counts, the total number of birds observed within each habitat type, the species abundance ranks within each habitat, and species ranks between the three habitats. Results of each of the above correlations revealed significant, positive relationships. Based on these results, abundance estimates generated by spot mapping and point counts are statistically similar and therefore, equally reliable in grassland habitats.

Despite significant positive correlations, the coefficient of determination (r^2) (Zar 1996) reveals that a high percent of variance from spot mapping is due to factors other than can be accounted for by the variation from point counts (Cody 1997). For example, 60% of spot mapping variation for the correlation of the total number of birds detected by each method was due to factors other than variation of point counts (Table 7). The correlation of the total number of birds detected within hay fields leaves 66% of variation unexplained (Table 7). For correlations based on species ranks, 51% of spot mapping variance was unexplained by point count variation in tallgrass sites, 52% in mixed grass sites, and 60% in hay fields. These high percentages of unexplained variance suggest that in fact the two methods may not be as equivalent as implied by the significant, positive correlations discussed above. A comparison of a larger sample size may reduce this unexplained variance. Due to the statistical significance of the correlations for this analysis, I will continue to discuss data from both spot mapping and point counts.

For the purposes of this study, point counts were an effective choice for surveying the small tallgrass patches that were examined because they covered the majority of the area of the patches. Bibby et al. (1992) describe point counts as more efficient in terms of data collected per unit effort than mapping counts but less efficient than transects. Point counts are particularly valuable in habitat studies that measure habitat characteristics at the census points, as was the case for this study. Point counts are also suitable for study of extensive areas but they do not provide the level of detail of mapped counts.

The mapping method is the most time consuming of the general abundance estimate methods for the number of birds finally counted. It is inefficient in this sense. The mapping method gains value if use is made of the fact that data are mapped, i.e. inferences can be drawn about relationships of birds and habitats (Bibby et al. 1992). Due to the small size of the remnant tallgrass patches, it would not be inefficient to conduct spot mapping for the entire habitat patches. Boundaries of the mapped areas could be based on existing landscape features, property boundaries, or boundaries of the Natural Area patches instead of a 100 m radius circle. These data could be combined with detailed vegetation maps for a thorough and refined understanding of these unique patches.

Based on efficiency, transects would be a more appropriate choice in the mixed grass sites on Davidson Mesa and the tallgrass site at the base of the mesa than point counts. Transects would logically and neatly fit on the narrow mesa top. They would also be the most appropriate method for traversing the narrow, steep slopes of the mesa, which seemed to have unique bird communities due to the presence of ponderosa pines. The Natural Area wraps around the foot and side of the mesa and could also be surveyed efficiently using transects.

Transects often allow for coverage of larger areas per unit time. This is a tradeoff that has increased attractiveness as habitats and bird communities become less complex (Reynolds et al. 1980). Choice of technique should be based upon the species of interest, time and personnel available, the number of and types of habitats censused, and the accuracy of the estimate that is required (Reynolds et al. 1980). It may in fact be that the appropriateness of methods varies depending on the species of interest and their behavioral ecology. For example, secretive species that forage on the ground may be flushed by an observer walking a transect or mapping an area. This allows for detection of a species that may be missed is point counts.

Ecological Associations

Avian assemblages of grasslands are locally simplistic and often dominated by only a few species (Knopf 1996). The highest avian species diversity (Table 3) found in this project was observed within the tallgrass sites (14 species), followed closely by non-native hay fields (12 species), and lastly mixed grass sites (8 species). Tallgrass sites also had the highest vegetation species diversity, followed by mixed grass sites, and finally hay fields.

Structurally, the tallgrass and hay field sites were fairly similar in that they were both fairly homogenous and had similar vegetation densities (Table 14). The fact that avian species diversity was highest in these two habitats suggests that greater structural homogeneity and cover may be more important for birds in these grasslands than plant species richness. The additional cover provided by the dense vegetation may also provide habitat for a larger range of invertebrates increasing the attractiveness of the area for foraging birds. Although not quantified, it appeared that the tallgrass sites had a higher abundance of grasshoppers and other conspicuous invertebrates than the other sites (Figure 1).

The greater avian species diversity in the tallgrass and hay field sites may also be a result of the invasion of exotic Russian-olive (*Elaeagnus angustifolia*) trees within the tallgrass sites and or the presence of irrigation ditches near the tallgrass and hay field sites. These edges and the non-native vegetation associated with them may provide greater variation of habitat around the periphery of the tallgrass and hay field study sites and thus increase the diversity of species observed within them. The fact that the tallgrass patches attracted the most diverse avian assemblage can be considered meaningful but it is not necessarily species diversity that defines the quality or ecological complexity of an area.

The presence of species that are considered ecologically associated with tallgrass prairie, including avian and plant species, can be an appropriate indicator of the Colorado Tallgrass Prairie's function as a small yet distinct tallgrass ecosystem. The avian assemblage of the Colorado Tallgrass Prairie includes several species that are known to be ecologically associated with tallgrass habitats. These include the

Grasshopper Sparrow, Western Meadowlark, and most notable, the Dickcissel (Knopf 1996). All of these species were considered breeding season residents within tallgrass habitats (Tables 1, 2). The vegetation of the tallgrass sites was composed of several characteristic tallgrass species including big blue stem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indian grass (*Sorghastrum avenaceum*). The presence of these plant and bird species within the tallgrass patches suggests that sufficient tallgrass components endure within the Colorado Tallgrass Prairie to maintain and attract species that are ecologically associated with this distinct habitat type.

There are only two avian species considered to be tallgrass-specific, the Dickcissel and Henslow's Sparrow (Knopf 1996). Of these, only the Dickcissel is the found in Boulder County, and it is considered rare or very local (Andrews and Righter 1992). Bock et al. (1995) observed that the Dickcissel was the only species that was present in Boulder's tallgrass prairie and not found in adjacent grassland habitats (Bock et al. 1995). Observations of Dickcissels in 1998 were primarily limited to tallgrass sites with one exception: two male Dickcissels were observed during one count in a non-native hay field. These may have been younger, unpaired males that were pushed to the less desirable habitats around the periphery of the tallgrass sites by more dominant males that successfully defended territories within the locally highest quality habitats.

Dickcissels are known to use shrubs that invade tallgrass prairie for nest sites (Zimmerman 1993). Two Dickcissel nests with fully feathered young (3 and 4 nestlings respectively) were located within the Colorado Tallgrass Prairie in Russian-olive trees. This establishes the first breeding record for this species in Boulder County. The presence of breeding Dickcissels indicates that they functionally inhabited the tallgrass sites by exploiting an exotic, invasive species. This adds to the complication of restoration goals because it is unclear whether the Russian-olive trees and shrubs are having a cumulatively positive or negative impact on the grassland avifauna. It would be useful to conduct extensive nest searching to determine if and at what level Brown-headed Cowbird parasitism is occurring in the area. Cowbirds could be taking advantage of elevated perch sites created by the Russian-olives for locating nests. No Brown-headed Cowbirds were detected during spot mapping or point counts at any of the grassland sites and no cowbird eggs were seen in any of the nests that were located. The only cowbird observed was along Cherryvale Road near a private residence. The lack of cowbirds in the study site may suggest that they have not infiltrated these areas or that the vegetation cover makes grassland host-nest location difficult and inefficient.

The species assemblage data collected can be seen as complimentary to existing data for Boulder County grasslands. Bock et al. (1995) compared the avian assemblages and abundance in the Colorado Tallgrass Prairie to that of the "True Prairie" to the east and found that 1) no grassland species was present in the Colorado Tallgrass Prairie that has not been observed nesting in the True Prairie; 2) some species characteristic of mixed grass prairie occurred in Boulder uplands but were not observed using tallgrass habitats; 3) the Boulder tallgrass avian assemblages were dominated primarily by species that were also abundant in surrounding habitats.

My project found similar results in that all avian grassland species observed within the Colorado Tallgrass Prairie are known to nest in the "True Prairie" to the east (Bock et al. 1995). I found conflicting results to the Bock et al. (1995) second point, most markedly by the presence of a territorial Horned Lark within the tallgrass site at the base of Davidson Mesa (Figure 1). This could be due to the fact that the area was highly disturbed by grazing. Horned Larks almost always occur where vegetation density is low and there is exposed soil (Andrews and Righter 1992). There was also evidence of historical mining activity on the slope of the mesa approximately 100 m away from this site, which provided some bare ground that may have been attractive to the Horned Lark. Although this tallgrass parcel is the largest of the three designated patches surveyed, it seemed to have the lowest quality vegetation. It lacked floristic characteristics of tallgrass prairie that the other two tallgrass sites included, such as the presence of switchgrass (*Panicum virgatum*), and Indian grass (*Sorghastrum avenaceum*). Structurally, it was the most heterogeneous (Table 13) of the tallgrass sites making it more similar to mixed grass sites than the other tallgrass sites. Despite these inconsistencies, it was determined to be the highest quality tallgrass within that parcel of the Colorado Natural Area. In terms of avian use, Dickcissels were not observed at this site, although Grasshopper Sparrows and Western Meadowlarks were observed.

Grasshopper Sparrows and Western Meadowlarks had the highest percent relative abundances of any species in tallgrass sites but were found in slightly higher abundances in surrounding mixed grass habitats (Table 6). Red-winged Blackbirds were by far the most abundant species in hay fields and were also the third most abundant species detected by point counts in tallgrass sites. These results are consistent with the findings of Bock et al. (1995) and confirm that the tallgrass patches are generally dominated by species that are more abundant in surrounding habitats.

However, one exception was found to these conclusions. The Dickcissel, which ranked the third most abundant species detected by spot mapping in tallgrass sites and had a relative abundance of 13% of total detections, was observed at its highest abundance in tallgrass sites (Tables 9,6). This suggests some level of preference for the tallgrass patches and, due to the tallgrass-specific ecological associations of this species, is a notable indicator of tallgrass ecosystem function. Bock et al. (1995) conclude that birds may persist in the remnant tallgrass patches only as portions of larger local populations occupying "the regional landscape mosaic". The presence of the breeding Dickcissels in the Colorado Tallgrass Prairie contradicts this conclusion and suggests that some uncommon species recognize the small patches as distinct habitats and select them non-randomly. The production and fledging of young Dickcissels lead me to conclude that not only are these patches distinct, but that they may functional as tiny, tallgrass ecosystems.

Results of this study suggest that the Colorado Tallgrass Prairie has maintained sufficient components to support a range of avian and plant species that are known to be ecologically characteristic of tallgrass prairie. Despite the small size of these remnant patches, they are successfully preserving tallgrass attributes that some avian species depend upon. Further research is necessary to determine if the tallgrass patches are functioning as distinct habitats for other groups, such as small mammals and invertebrates.

Grassland birds are declining significantly worldwide. Aggressive protection, restoration, research, and adaptive management is vital for the survival of these unique species and habitats. Knopf (1996) points out that to many naturalists, native birds of prairie landscapes are the most boring, drabbest, and ecologically least significant of all of the North American avifauna. Changing these perspectives on the value and appreciation of grassland biota is critical in the preservation of North America's remaining grasslands.

LITERATURE CITED

Andrews, R. and R. Righter. 1992. Colorado Birds. Denver Museum of Natural History. Denver, CO, 442 pp.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Axelrod, D. I. 1985. Rise of the grassland biome, Central North America. The Botanical Review. 51(2):163-201.

Bailey, A. M. and R. J. Neidrach. 1965. Birds of Colorado. Denver Museum of Natural History. Denver, CO, 895 pp.

Bamforth, D. B. 1987. Historical documentation of bison ecology on the Great Plains. *Plains Anthropologist* 32:1-16.

Barker, R. J., J. R. Sauer, W. A. Link. 1993. Optimal allocation of point-count sampling effort. *The Auk* 110(4):752-758.

Bart, J. and J. D. Schoultz. 1984. Reliability of singing bird surveys: changes in observer efficiency with avian density. *The Auk* 101: 307-318.

Bibby, C. J., N. D. Burgess, and D. A. Hill. 1992. Bird Census Techniques. Academic Press Limited, London.

Bock, C. E., J. H. Bock, and B. C. Bennett. 1995. The avifauna of remnant tallgrass prairie near Boulder, Colorado. *The Prairie Naturalist* 27(3):September.

Bock, C. E. and J. H. Bock. 1997. Biodiversity of Boulder Open Space Grasslands at a Suburban / Agricultural Interface: Third Annual Report. Report prepared for the City of Boulder Open Space / Real Estate Department.

Branson, F. A., R. F. Miller, and I. S. McQueen. 1965. Plant communities and soil moisture relationships near Denver, Colorado. *Ecology* 46:311-319.

Bunin, J. 1985. Vegetation of the City of Boulder Open Space lands. Unpublished report. Natural Science Associates, Inc. Boulder, CO. 114pp.

City of Boulder Open Space and Colorado Natural Areas Program. 1986. Colorado Tallgrass Prairie Management Plan.

Clements, F. E. 1936. Nature and structure of the climax. *Journal of Ecology* 24:252-84.

Cody, R. P. and J. K. Smith. 1997. Applied Statistics and the SAS Programming Language, 4th edition. Prentice Hall, Inc. New Jersey, 445 pp.

DeSante, D. F. 1986. A field test of the variable circular-plot censusing method in a Sierran sub-alpine forest habitat. *The Condor* 88(2):129-142.

Dickson, J. G. 1978. Comparison of breeding bird census techniques. *American Birds* 32 (1):10-13.

Flores, D. L. 1996. A long love affair with an uncommon country. *in* F. B. Samson and F. L. Knopf (eds) Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D. C., 339pp.

Gibbons, D. W., D. A. Hill, and W. J. Sutherland. 1996. Birds. Pp. 227-255 *in* Ecological census techniques: A handbook. William J. Sutherland, Cambridge University Press, Great Britain.

Gutzwiller, K. J. 1993. Refining the use of point counts for winter studies of individual species. *The Wilson Bulletin* 105(4):612-627.

Henderson, J. 1909. An annotated list of birds of Boulder County, Colorado. *University of Colorado Studies*, 6(3):219-242.

James, S. L. 1930. The herbaceous vegetation of two mesas near Boulder, Colorado. Unpublished thesis, University of Colorado, Boulder, 41 pp.

Kendeigh, S. C. 1941. Birds of a prairie community. *Condor* 43:165-174.

Knopf, F. L. 1996. Prairie legacies- Birds *in* F. B. Samson and F. L. Knopf (eds) Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D. C., 339pp.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons. Ney York, 547 pp.

Ralph, C. J., J. R. Sauer, and S. Droege. 1995. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GT-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U. S. Department of Agriculture, 187 pp.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot methodfor estimating bird numbers. *Condor* 82:309-313.

Rotenberry, J. T. and J. A. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. *Ecology*. 61(5):1228-1250.

Samson, F. B. and F. L. Knopf. 1994. Prairie conservation in North America. *Bioscience* 44:418-21.

Samson, F. B. and F. L. Knopf. 1996. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D. C. 339pp.

Steinaur, E. M. and S. L. Collins. 1996. Prairie ecology- the tallgrass prairie. *in* F. B. Samson and F. L. Knopf (eds) Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D. C. 339pp.

Thompson, R. W. and J. G. Strauch, Jr. 1986. Habitat use by breeding birds on City of Boulder Open Space, 1986. Prepared for the City of Boulder Open Space / Real Estate Department by Western Ecosystems, Inc.

Verner, J. and L. V. Ritter. 1986. Hourly variation in morning point counts of birds. *Auk* 103:117-124.

Vestal, A. G. 1914. Prairie vegetation of a mountain-front area in Colorado. *Botanical Gazette* 58:377-400.

Weber, W. A. 1990. Colorado flora: Eastern slope. University Press of Colorado. Niwot, Colorado. 396pp.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. *Ornithological Monographs* 8:1-93.

Wiens, J. A. 1973. Pattern and process in grassland bird communities. *Ecological Monographs*. 43:237-270.

Williams, A. B. 1936. The composition and dynamics of a Beech-Maple climax community. *Ecological Monographs* 6(3):317-408.

Zar, J. H. 1996. Biostatistical Analysis, 3rd edition. Prentice Hall. New Jersey, 662 pp.

Zimmerman, J. L. 1993. The Birds of Konza. University Press of Kansas. Lawrence, KA, 186 pp.

Appendix A. Scientific names of avian species observed in study sites.

COMMON NAME	SCIENTIFIC NAME
Mallard	*Anas platyrhynchos*
Red-tailed Hawk	*Buteo jamaicensis*
Killdeer	*Charadrius vociferus*
Common Snipe	*Gallinago gallinago*
Mourning Dove	*Zenaida macroura*
Common Nighthawk	*Chordeiles minor*
Eastern Kingbird	*Tyrannus tyrannus*
Black-billed Magpie	*Pica pica*
Horned Lark	*Eremophila alpestris*
American Robin	*Turdus migratorius*
European Starling	*Sturnus vulgaris*
Vesper Sparrow	*Pooecetus gramineus*
Lark Bunting	*Calamospiza melanocorys*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Song Sparrow	*Melospiza melodia*
Dickcissel	*Spiza americana*
Bobolink	*Dolichonyx oryzivorus*
Red-winged Blackbird	*Agelaius phoeniceus*
Western Meadowlark	*Sturnella neglecta*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Bullock's Oriole	*Icterus bullockii*

Appendix B. Vegetation species composition and estimated percent cover by habitat, site, and vegetation plot. Species names follow Weber 1990.

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Hay Field	1	1	Carex lanuginosa	25-50
			Carex nebrascensis	25-50
			Festuca pratensis	5-25
			Lotus tenuis	5-25
			Phleum pratense	5-25
			Plantago lanceolata	5-25
			Trifolium pratense	5-25
			Triglochin maritimum	5-25
		2	*Festuca pratensis*	25-50
			Phleum pratense	25-50
			Spartina pectinata	25-50
			Trifolium pratense	25-50
		3	*Dactylis glomerata*	5-25
			Festuca pratensis	50-75
			Lotus tenuis	5-25
			Phleum pratense	50-75
			Poa pratensis	5-25
			Trifolium pratense	50-75
		4	*Lotus tenuis*	5-25
			Plantago lanceolata	50-75
			Plantago major	1-5
			Scirpus lineatus	1-5
			Spartina pectinata	50-75
			Trifolium pratense	1-5
			Triglochin maritimum	25-50
Hay field	2	1	*Carex nebrascensis*	2-25
			Festuca pratensis	1-5
			Glyceria striata	1-5
			Scirpus americanus	5-25
			Spartina pectinata	50-75
			Triglochin maritimum	5-25
		2	*Convolvulus arvensis*	25-50
			Festuca pratensis	>75
			Phleum pratense	50-75
			Trifolium pratense	25-50
		3	*Festuca pratensis*	25-50
			Glyceria striate	1-5
			Phleum pratensis	25-50
			Spartina pectinada	25-50
			Trifolium pratense	1-5

			Trifolium pratense	50-75
		4	*Cichorium intybus*	1-5
			Dactylis glomerata	50-75

Appendix B. Continued

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Hay field	3	4	*Glyceria striate*	5-25
			Iris missouriensis	1-5
			Lotus tenuis	1-5
			Phleum pratense	50-75
			Rumex crispus	5-25
			Spartina pectinata	25-50
			Trifolium pratense	50-75
Tallgrass	1	1	*Ambrosia psilostachya,* variety *coronopifolia*	1-5
			Andropogon gerardii	50-75
			Dalea candida oligophylla	25-50
			Elaegnus angustifolia	5-25
			Oligoneuron rigidum	5-25
			Panicum virgatum	5-25
			Phleum pratense	1-5
			Rosa arkansana	50-75
			Sorghastrum avenaceum	1-5
			Virgulus falcatus	5-25
		2	*Andropogon gerardii*	25-50
			Panicum virgatum	50-75
			Psoralea tenuiflora	2-25
			Ratibida columnifera	5-25
			Rosa arkansana	50-75
			Trifolium pratense	5-25
		3	*Ambrosia psilostachya,* variety *coronopifolia*	1-5
			Andropogon gerardii	5-25
			Asclepias speciosa	5-25
			Cirsium arvense	5-25
			Panicum virgatum	50-75
			Phyla cuneifolia	5-25
			Psoralea tenuiflora	1-5
			Rosa arkansana	5-25
			Scirpus americanus	5-25
			Spartina pectinata	50-75
		4	*Agrostis gigantea*	>75
			Critesion jubatum	25-50

			Epilobium spp.	1-5
			Juncus longistylis	1-5
			Scirpus americanus	5-25

Appendix B. Continued

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Tallgrass	2	1	*Ambrosia psilostachya,* variety *coronopifolia*	25-50
			Andropogon gerardii	25-50
			Asclepias incarnata	5-25
			Bromopsis inermis	5-25
			Dalea candida oligophylla	5-25
			Panicum virgatum	25-50
			Sorghastrum avenaceum	5-25
			Taraxacum officinale	5-25
			Trifolium pratense	5-25
		2	*Agrostis gigantea*	5-25
			Ambrosia psilostachya, variety *coronopifolia*	25-50
			Andropogon gerardii	25-50
			Asclepias incarnata	5-25
			Asclepias speciosa	5-25
			Cichorium intybus	25-50
			Cirsium arvense	1-5
			Convolvulus arvensis	25-50
			Dactylis glomerata	25-50
			Rosa arkansana	5-25
			Taraxacum officinale	25-50
		3	*Asclepias speciosa*	5-25
			Carex nebrascensis	50-75
			Panicum virgatum	50-75
		4	*Agrostis gigantea*	25-50
			Ambrosia psilostachya, variety *coronopifolia*	25-50
			Asclepias incarnata	50-75
			Asclepias speciosa	50-75
			Cirsium arvense	5-25
			Elaegnus angustifolia	5-25
			Elytrigia repens	25-50
			Panicum vigatum	25-50

	3	1	*Ambrosia psilostachya,* variety *coronopifolia*	5-25
			Andropogon gerardii	50-75
			Artemisia ludaviciana	5-25
			Bromopsis inermis	5-25
			Psoralea tenuiflora	5-25
			Rosa arkansana	25-50

Appendix B. Continued

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Tallgrass	3	2	*Ambrosia psilostachya,* variety *coronopifolia*	25-50
			Andropogon gerardii	25-50
			Carex praegracilis	25-50
			Helianthus rigidus, variety subrhomboideus	5-25
			Heterotheca villosa	5-25
			Opuntia spp.	5-25
			Poa pratensis	25-50
			Psoralea tenuiflora	5-25
			Rosa arkansana	5-25
			Solidago canadensis	25-50
			Thelesperma megapotamicum	5-25
			Tragopogon dubius	5-25
			Virgulus falcatus	25-50
		3	*Ambrosia psilostachya,* variety *coronopifolia*	5-25
			Andropogon gerardii	25-50
			Liatris punctata	5-25
			Neolepia campestre	5-25
			Phacelia heterophylla	5-25
			Psoralea tenuiflora	5-25
			Sporobolus heterolepis	5-25
			Tragopogon dubius	5-25
			Virgulus falcatus	5-25
		4	*Ambrosia psilostachya,* variety *coronopifolia*	25-50
			Andropogon gerardii	25-50
			Heterotheca villosa	25-50
			Poa pratensis	25-50

			Psoralea tenuiflora	25-50
			Rosa arkansana	5-25
			Thelesperma megapotamicum	25-50
			Virgulus falcatus	25-50
Mixed	1	1	*Ambrosia psilostachya,* variety *coronopifolia*	50-75
			Artemisia frigida	5-25
			Artemisia ludavisiana	5-25
			Oligosporus pacificus	5-25
			Pascopyrum smithii	1-5
			Phacelia heterophylla	5-25

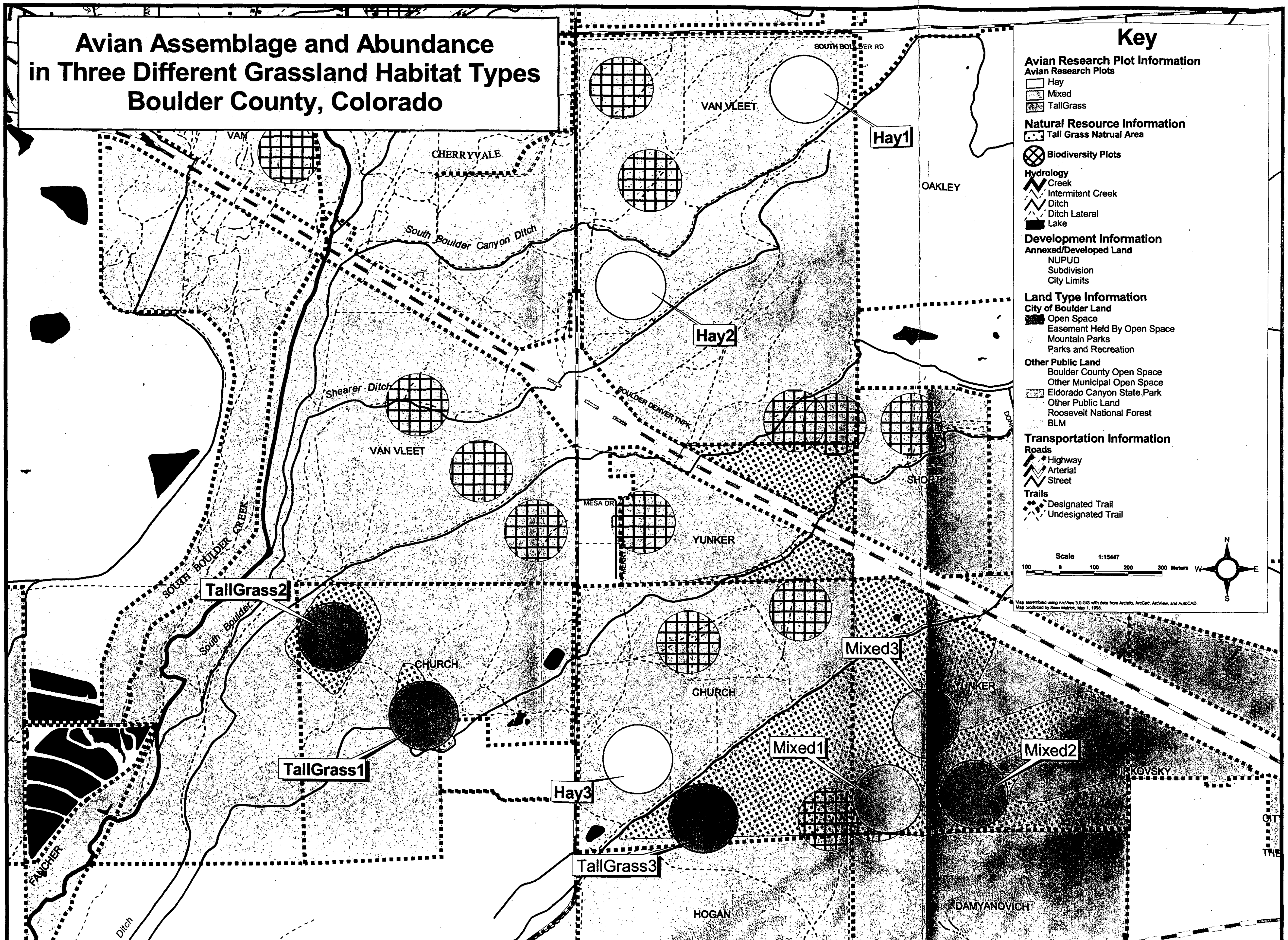
Appendix B. Continued

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Mixed	1	1	*Psoralea tenuiflora*	5-25
		2	*Ambrosia psilostachya,* variety *coronopifolia*	1-5
			Artemisia frigida	1-5
			Bouteloua curtipendula	1-5
			Cirsium arvense	1-5
			Gastrolychnis drummondii	1-5
			Oligosporus pacificus	1-5
			Opuntia spp.	25-50
			Pascopyrum smithii	1-5
			Psoralea tenuiflora	25-50
			Silene antirrhina	1-5
			Sorghastrum avenaceum	50-75
		3	*Ambrosia psilostachya,* variety *coronopifolia*	5-25
			Erigeron spp.	1-5
			Oligosporus pacificus	1-5
			Opuntia spp.	25-50
			Pascopyrum smithii	5-25
			Psoralea tenuiflora	1-5
			Silene antirrhina	1-5
			Sorghastrum avenaceum	50-75
			Yucca glauca	1-5
		4	*Adenolium lewisii*	1-5
			Ambrosia psilostachya, variety *coronopifolia*	1-5
			Artemisia frigida	1-5

			Psoralea tenuiflora	5-25
			Pterogonum alatum	50-75
		2	*Andropogon gerardii*	25-50
			Artemisia frigida	25-50
			Convolvulus arvensis	25-50
			Dianthus armeria	50-75
			Heterotheca villosa	25-50
			Koeleria macrantha	25-50
		3	*Andropogon gerardii*	25-50
			Artemisia frigida	25-50
			Artemisia ludoviciana	5-25
			Convolvulus arvensis	25-50
			Dianthus armeria	50-75
			Heterotheca villosa	25-50
			Koeleria macrantha	25-50
		4	*Buchloe dactyloides*	50-75
			Coryphantha spp.	5-25
			Erigeron spp.	50-75

Appendix B. Continued

HABITAT	SITE	PLOT	SPECIES	ESTIMATED % COVER
Mixed	3	4	*Gutierrezia sarothrae*	1-5
			Koeleria macrantha	1-5
			Lactuca serriola	1-5
			Yucca glauca	25-50


Avian Assemblage and Abundance
in Three Different Grassland Habitat Types
Boulder County, Colorado
Key
Avian Research Plot Information
Avian Research Plots
Hay
Mixed
TallGrass
Natural Resource Information
Tall Grass Natrual Area
Biodiversity Plots
Hydrology
Creek
Intermitent Creek
Ditch
Ditch Lateral
Lake
Development Information
Annexed/Developed Land
NUPUD
Subdivision
City Limits
Land Type Information
City of Boulder Land
Open Space
Easement Held By Open Space
Mountain Parks
Parks and Recreation
Other Public Land
Boulder County Open Space
Other Municipal Open Space
Eldorado Canyon State Park
Other Public Land
Roosevelt National Forest
BLM
Transportation Information
Roads
Highway
Arterial
Street
Trails
Designated Trail
Undesignated Trail
Scale 1:15447
100 0 100 200 300 Meters
N
E
S
W
Hay1
Hay2
Hay3
Mixed1
Mixed2
Mixed3
TallGrass1
TallGrass2
TallGrass3
VAN VLEET
CHERRYVALE
OAKLEY
South Boulder Canyon Ditch
Shearer Ditch
BOULDER DENVER TRPK
MESA DR
YUNKER
SHORT
CHURCH
SOUTH BOULDER CREEK
South Boulder
JIRKOVSKY
HOGAN
DAMYANOVICH
FANCHER
Ditch