FINAL PERFORMANCE REPORT

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EFFECTS OF LAND COVER CHANGE IN SANDY SANDERS, PACKSADDLE, AND COOPER WILDLIFE MANAGEMENT AREAS ON STATE BIRDS OF GREATEST CONSERVATION NEED

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

September 15, 2004 through September 14, 2009

FINAL REPORT

State: Oklahoma **Grant Number:** T-22-P

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Grant Name: Effects of Land Cover Change in Sandy Sanders, Packsaddle, and Cooper Wildlife Management Areas on State Birds of Greatest Conservation Need

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Abstract

Grassland and Shrubland songbirds are species of conservation concern in western Oklahoma. Existing literature suggests shrub encroachment may be a significant correlate of faunal turnover in this region. We surveyed birds and vegetation communities at Cooper, Packsaddle and Sandy Sanders Wildlife Management Areas in 2006 and 2007. We also compared plant communities evident on contemporary (2005) and historic (1937 or 1941) aerial photographs. Analyses of plant communities suggested the primary vegetation change was expansion of the riparian corridors in Cooper, Packsaddle and Sandy Sanders Wildlife Management Areas over the past 60 years. This expansion likely contributes to increases in cosmopolitan avifauna at the expense of grassland and shrub land adapted species. Point counts detected a number of Tier I to Tier III species of conservation concern that included Bell's Vireos, Cassin's Sparrows, and Painted Buntings. Overall we found that (1) within upland habitats the occurrence of grassland bird species was negatively related to percent shrub cover at individual point count locations and (2) that species with declining regional population trends tended to co-occur with species that had stable population trends. Based on these patterns we suggest that ongoing interspecific behavioral interactions may play an important role in population declines of grassland and shrub land species. In particular widespread species such as American Robins, Northern Mockingbirds, and House Finches that rely on the expanded riparian habitats may also use the upland habitats for foraging and other activities. When found in upland habitats many of these widespread species are found primarily in shrubs. Therefore we suggest that any shrub management narrowly target those species of shrubs that tend to be more common in the uplands than was historically the case (e.g. eastern redcedar). We think that broader shrub control could potentially negatively impact shrub obligate avifauna of high conservation concern such as Bell's Vireo, which is a Tier I species.

Objectives

Evaluate the effect of vegetation change on the distribution and abundance of Oklahoma's birds of greatest conservation need within three wildlife management areas in western Oklahoma and the surrounding lands (1/4 section).

Introduction

Numerous grassland and shrub land birds are species of conservation concern in Oklahoma (Tier I through Tier III, ODWC 2004). Many of the species categorized as Tier I enjoy some form of federal status and are the subject of species-specific monitoring programs in Oklahoma and elsewhere (e.g., Mountain Plover, Lesser Prairie-chicken, and Black-capped Vireo). However, current trends, distributions, and abundances of less critically threatened species are more poorly known. Examples include Cassin's Sparrow (*Ammodramus cassini*), Bell's Vireo (*Vireo bellii*), and Painted Buntings (*Passerina ciris*). Our objective was to better document the occurrence of these and other declining, but less well-studied species at three wildlife management areas in western Oklahoma.

Method

Between 2005 and 2007 we sampled vegetation communities and birds at Cooper, Packsaddle and Sandy Sanders Wildlife Management areas. In addition we digitized and compared recent (2005) and historic (1937 or 1941) aerial photographs of the WMAs. Our objectives were to describe the current vegetation composition and avian assemblages with particular emphasis on documenting the abundance and habitat use of birds of conservation concern. This report is divided into two primary sections. Section 1 describes vegetation surveys, digitization of the aerial photographs and the resulting maps from both 2005 and 1937 or 1941. Section 2 describes the richness, distribution, and abundance of avifaunal on these wildlife management areas with respect to their population trends and shrub cover.

Study Areas

Packsaddle WMA covers 62.9 km^2 (15,550 acres), in Ellis County, Oklahoma. Located in the mixed grass prairie, it is a mixture of rolling sand hills and wooded bottoms with the South Canadian River as its southern boundary. Potential natural vegetation of the area is sand shinnery oak *(Quercus havardii)* and mixed grass eroded plains (Duck and Fletcher, 1943). In Oklahoma, shinnery oak is typically associated with the mixed grass species of sand dropseed *(Sporobolus cryptandrus)* and little bluestem *(Schizachyrium scoparium)* (Hoagland, 2000). This association is evident in Packsaddle WMA as little bluestem and sand dropseed are two of the dominant grasses.

In general, uplands areas consist primarily of mixed grass species including big bluestem *(Andropogon gerardii)*, indian grass *(Sorghastrum nutans)*, little bluestem, sideoats grama *(Bouteloua curtipendula)*, and buffalo grass *(Bouteloua dactyloides)*, as well as woody species such as sand shinnery oak, sand sagebrush *(Artemisia filifolia)*, and Chickasaw plum *(Prunus angustifolia)*. Bottomlands are dominated by trees, such as cottonwood *(Populus deltoides)*, American elm *(Ulmus americana)*, hackberry *(Celtis occidentalis)*. Average annual precipitation in this area is approximately 63.5 cm (25 inches) (OCS, 2007).

Packsaddle WMA is located in the High Plains and Western Redbud Plains (Curtis and Ham, 1972) in the Osage Plains Physiographic Province (Hunt, 1974). The surface geology is comprised of Tertiary sand, clay and gravel deposited by ancient rivers flowing from the Rocky Mountains (Branson and Johnson, 1979). Soils are typical of uplands, and consist primarily of the Brownfield, Nobscot and Pratt Series. The Pratt Associations consist of loamy fine sand, and the Brownfield and Nobscot Associations consist of fine sand (Cole et al., 1966). They can be hummocky or rolling, tend to be deep, can be severely eroded and generally exhibit a well defined drainage pattern (Cole et al., 1966).

Cooper WMA covers 66.4 km^2 (16,415 acres) in northwestern Woodward and south central Harper counties. The potential natural vegetation of this site is the *Artemisia filifolia / Sporobolus cryptandrus - Schizachyrium scoparium* shrubland association (Duck and Fletcher, 1943). The topography consists of upland rolling sand hills and river bottom. Upland areas are characterized by mixed grass prairie and sand sagebrush, interspersed with Chickasaw plum thickets. The river bottom vegetation is open and contains herbaceous communities interspersed with woody species such as cottonwood *(Populus deltoides)*, American elm *(Ulmus americana)*, hackberry *(Celtis occidentalis)*, eastern redcedar *(Juniperus virginiana)*, Chickasaw plum *(Prunus angustifolia)*, black willow *(Salix nigra)* and salt cedar *(Tamarix ramosissima)*. Average annual precipitation in this area is approximately 63.5 cm (25 inches) (OCS, 2007).

Cooper WMA is located in the Western Sand Dune Belts and the Western Sandstone Hills (Curtis and Ham, 1972) in the Osage Plains Physiographic Province (Hunt, 1974). The surface geology is comprised of Permian sandstone and shale in the uplands and Quaternary sand, silt, clay and gravel deposited within the Canadian River floodplain (Branson and Johnson, 1979). Soils are typical of uplands, and consist primarily of the Pratt, Tivoli, Yahola, Woodward and Quinlan Associations. The Pratt Associations consist of fine sandy loam and loamy fine sand, and the Tivoli Association consists of fine sand, the Yahola Association consists of fine sand loam and the Woodward and Quinlan Associations consist of loam (Nance et al., 1960). They can be hummocky or rolling, tend to be deep, can be severely eroded and generally exhibit a well defined drainage pattern (Nance et al., 1960).

Sandy Sanders WMA covers 74.5 km^2 (18,650 acres) in Greer and Beckham counties in southwest Oklahoma. The potential natural vegetation of this site consists of the *Juniperus pinchotii/Bouteloua* (*curtipendula, hirsuta*) woodland association and the *Prosopis glandulosa / Bouteloua gracilis - Buchloe dactyloides* shrubland association (Duck and Fletcher, 1943). The topography/geomorphology consists of rugged terrain, extending along the Elm Fork of the Red River. Honey mesquite *(Prosopis glandulosa)*, redberry juniper *(Juniperus pinchotii)*, and mixed grasses dominate this area. The central third of the area contains dense stands of red berry juniper, with a transition to mesquite savanna and mixed grass prairie extending outward from the center. Although the Elm Fork River flows year round, riparian vegetation is limited to dense stands of salt cedar. Creek bottoms are vegetated with taller, denser grass and scattered trees, including cottonwood, hackberry and American elm. The average annual precipitation for the area is approximately 66 cm (26 inches) (OCS, 2007).

Sandy Sanders WMA is located in the Mangum Gypsum Hills, Western Sandstone Hills and Central Redbud Plains (Curtis and Ham, 1972) in the Osage Plains Physiographic Province (Hunt, 1974). The surface geology is comprised of Permian sandstone and shale in the uplands and Quaternary sand, silt, clay and gravel deposited within the Canadian River floodplain (Branson and Johnson, 1979). Soils are typical of uplands, and consist primarily of the Cornick-Vinson, Quanah-Talpa, Spur, Tillman, Cottonwood and Vernon Series. The Cornick-Vinson, Quanah-Talpa, Spur, Tillman and Cottonwood Associations are loamy, and the Vernon Associations are clayey (Ford et al., 1980; Frie et al., 1967). They tend to be rolling, moderate to deep, and generally exhibit a well-defined drainage pattern (Ford et al., 1980; Frie et al., 1967).

Current land use at all three of the WMA's consists primarily of cattle grazing with regulated hunting during various times of year. Primitive camping is allowed in specific areas within the WMA's that are consistently mowed and maintained. In addition, a few small agricultural plots occur at each WMA.

Section 1 - Current and Historic Vegetation Composition and Mapping

A primary concern in arid and semi-arid grasslands world wide is the proliferation of woody shrubs owing to grazing practices, fire management and climate change. While there is some evidence of increasing shrub densities in western Oklahoma and responses to this increase by birds (Coppedge et al. 2002), it is not clear that shrub encroachment has occurred at Wildlife Management Areas managed by the ODWC . To determine if the aerial coverage of shrubs has increased over the past 70 years we compare the shrub cover from 1937 to that in 2005 at three WMAs.

Vegetation Data and Analysis

Field surveys were conducted on the following schedule: Cooper WMA, May-September 2006; Packsaddle and Sandy Sanders WMA, May-September 2007. The Modified-Whittaker sampling technique was selected because it has proven effective for the analysis of species richness and diversity at multiple scales and has been successfully employed in grassland studies (Stohlgren et al., 1995; Stohlgren et al., 1997; Stohlgren et al., 1998; Stohlgren et al., 1999; Barnett and Stohlgren, 2003; Leis and Engle, 2003). A Modified-Whittaker plot consists numerous, nested quadrats that are arranged to reduce spatial autocorrelation. The largest plot is 20m x 50m. Within this large plot, a 5m x 20m plot is nested in the center, with two 2m x 5m subplots in the northwestern and southeastern corners of the 20m x 50m plot, with four 0.5m x 2m subplots bordering the outside 20m x 50m plot and another eight 0.5m x 2m subplots bordering the inside of the main 0.5m x 2m subplots (Stohlgren et al., 1995). In addition, eight more 5m x 20m plots were randomly located to ascertain vegetation cover only. Although they are only at one scale, these extensive plots allowed for vegetation cover to be determined throughout a larger area (Barnett and Stohlgren, 2003). Percent cover was visually estimated at each of these plots, as well as the 12 0.5m x 2m subplots located within the Modified-Whitaker plots (*Tables 1-3*).

The most dominant vegetation encountered at the Cooper WMA were sand sagebrush *(Artemisia filifolia)*, little bluestem *(Schizachyrium scoparium)*, annual ragweed *(Ambrosia artemisiifolia)*, downey brome *(Bromus tectorum)* and blue grama *(Bouteloua gracilis)*. The most dominant vegetation encountered at the Packsaddle WMA were sand shinnery oak *(Quercus havardii)*, little bluestem, annual ragweed and sand sagebrush. The most dominant vegetation encountered at the Sandy Sanders WMA were honey mesquite *(Prosopis glandulosa)*, little bluestem, prairie broomweed *(Amphiachyris dracunucloides)* and blue grama. In each WMA, the most dominant species was the particular woody plant known to occur in that location, followed by mixed grasses.

Plant Associations of Particular Interest
***Quercus havardii /Sporobolus cryptandrus - Schizachyrium scoparium* Shrubland Association**

Sand shinnery oak is a rhizomatous deciduous shrub that grows to an average height of 1.0m, and occurs on sandy soils from eastern New Mexico across Texas high plains and into western Oklahoma (Pettit, 1986, Dhillion et al., 1999). Because shinnery oak prefers sandy soils, its' densities tend to increase with increasing sand content and decrease with increasing clay content (Petit, 1986). It is a member of the Lepidobalanus (white oak) subfamily, and exhibits vegetative and reproductive characteristics typical of the *Quercus* genus (Pettit, 1986, Dhillion et al., 1999). The name shinnery is derived from the French word chenneire, which translates to an oak that is shin high (Petit, 1986). True shinnery is typically shin high, but there is another hybridized variety of that gets much larger.

In western Oklahoma, shinnery oak is often found within mottes of hybridized shinnery and post oaks (*Quercus stellata*) growing to a height of 6-8m (Pettit, 1986). Individual stems of hybridized shinnery can live over 80 years, while true shinnery only lives 11-15 years (Petit, 1986). Shinnery oak occurs in semiarid climates with annual precipitation ranging from 35-76 cm where approximately 80% of precipitation falls between April and October (Dhillon and Mills, 1999).

Shinnery oak is a management problem when it grows in dense stands. It can be such an aggressive dominant that it will compete with grasses and forbs for water and nutrients at a highly successful rate (Petit, 1986). However, cattle can't tolerate a diet that is high in oak as it can be destructive to the liver and kidneys (Petit, 1986).

***Artemisia filifolia/Sporobolus cryptandrus - Schizachyrium scoparium* Shrubland Association**

Sand sagebrush, a member of the composite family (Asteraceae) is an aromatic small shrub that grows to an average height of 1m. It is found on deep sandy soils and stabilized dunes in the western plains from eastern Wyoming and South Dakota southward to Arizona and New Mexico and extending into Texas, Oklahoma and Mexico (Goodrich, 2005). It has sparse filiform leaves and has the capacity to spread out in a landscape with open vegetation cover (Goodrich, 2005).

Sand sagebrush shrublands occur throughout western Oklahoma, including the Panhandle. Common associated species include sand bluestem *(Andropogon hallii),* sideoats grama *(Bouteloua curtipendula),* blue grama *(B. gracilis),* giant sandreed *(Calamovilfa gigantean),* Chickasaw plum *(Prunus angustifolia),* yellow sundrops *(Calylophus serrulatus),* Schweinitz's flatsedge *(Cyperus schweinitzii),* annual buckwheat *(Eriogonum anuum)*, and fragrant sumac *(Rhus aromatica).*

***Juniperus pinchotii/Bouteloua* (*Curtipendula, hirsuta*) Woodland Association and *Prosopis glandulosa / Bouteloua gracilis - Buchloe dactyloides* Shrubland Association**

Redberry juniper *(Juniperus pinchotti)*, a member of the juniper family (Cupressaceae) It is an evergreen coniferous shrub that grows to an average height of 3m. Its range includes portions of New Mexico, Arizona, Oklahoma, Texas and Mexico. It is considered an invasive species on most range sites, and it has very little economic value (Dye et al., 1995). As redberry juniper canopy cover increases, herbaceous cover decreases dramatically (McPherson and Wright, 1990). Redberry juniper and other species in the juniper family have been found to have drastic effects on herbaceous vegetation in grasslands in Texas, New Mexico and Oklahoma (Schott and Pieper, 1985; Engle et al., 1987; Dye et al., 1995).

Prosopis glandulosa (honey mesquite) is a leguminous arborescent shrub that grows to an average height of 6-7m. It occurs on dry sandy soils from New Mexico and Arizona into western Oklahoma, Texas and northern Mexico (Archer, 1994). Honey mesquite has been encroaching into Texas rangelands for 100 years, resulting in the conversion of grasslands and open savannas to woodlands (Johnston, 1963; Martin, 2003). The increase in honey mesquite cover has caused a subsequent decrease in herbaceous vegetation (Archer, 1989; Bahre and Shelton, 1993; Archer, 1994; Martin, et al., 2003). Land settlement, grazing by domestic livestock, and fire suppression have been the primary causes for this change in vegetation patterns (Bahre and Shelton, 1993; Archer, 1994).

Duck and Fletcher (1943) mapped the occurrence of honey mesquite as limited to the far southwest corner of the state. It is known to have occurred in that region since the mid-nineteenth century, when Marcy wrote about the extensive mesquite shrublands encounter during his expedition to the source of the Red River (Foreman, 1937). Since that time, the range of honey mesquite has expanded in Oklahoma to the Kansas border. It was first reported in the Panhandle in 1928 (Tate, 1928). Today, honey mesquite shrublands occur throughout western Oklahoma, including Beckham, Comanche, Cotton, Ellis, Greer, Harmon, Jackson, Jefferson, Kiowa, Major, Roger Mills, Stephens, and Tillman counties. Although honey mesquite shrublands do not occur in eastern Oklahoma, individual occurrences have been reported from counties such as Tulsa, Coal, Pittsburgh, and Osage. Cattle from Texas have historically been wintered on ranches in these counties. In fact, the herbarium record from Tulsa County, collected in 1957, states that "Pasture owner stated trees appeared following feeding of cattle from Texas 15 years ago" (Hoagland et al. 2006). Associated species in the honey mesquite woodlands include *Ambrosia artemisiifolia, Amphiachyris dracunculoides, Bothriochloa saccharoides, Bouteloua gracilis, Opuntia polyacantha*, and *Schizachyrium scoparium* (Hoagland, 2000).

Vegetation/Land Cover Change

Contemporary aerial photographs of the study areas from 2005 were obtained through the Center for Spatial Analysis website at the University of Oklahoma to compare current vegetation distribution to historic patterns. In addition, historic aerial photographs from 1937 or 1941 were obtained through an independent distributor in conjunction with the National Archives in Washington, DC. Because the historic photographs are scanned mapped datasets, they don't contain spatial reference information, and therefore must referenced to contemporary images so their raster data will correspond with the contemporary data from the same location (Ormsby et al 2004). In doing this, the coordinate system will match the coordinate system that the contemporary images use. Because it is nearly impossible to georeference historic images to contemporary ones with 100% accuracy, a residual error occurs with the placement of each individual control point that is selected on the two maps. Control points are locations that can be accurately identified on the raster dataset (historic image) and the real-world coordinates from the contemporary image (Ormsby et al 2004). Examples are road intersections, stream intersections, rock outcrops, or in some cases plowed (disturbed) fields. Residual errors were kept below 10%, and in most cases, the error was below 5%. The higher errors occurred when there were minimal features to be used for georeferencing. These higher residual error percentages occurred most often on the Cooper WMA maps because the area was (and still is) very uniform. Both Packsaddle and Sandy Sanders contained enough accurate features (ie. roads, fields and rock outcrops) that it was easier to georeference the historic images to the contemporary ones. However, because of the uniformity of the vegetation distribution at the Cooper WMA, the residual errors from georeferencing should not have drastic effects on the overall vegetation/land cover distributions.

Dominant vegetation/land cover types were identified for each WMA and digitized using ArcGIS on both the historic and contemporary aerial photographs. Individual maps were created for both the historic and contemporary land cover patterns for each WMA, totaling six maps altogether. Within each map, separate layers were created for each of the dominant vegetation types, upon which the specified vegetation type was digitized. Creating individual layers for each vegetation type allowed for more ease in identifying and interpreting vegetation patterns and in calculating land cover totals. In addition to vegetation cover, prominent roads and hydrologic features were also digitized where applicable.

Features were digitized at fine scales to maintain the highest level of accuracy. Most features were digitized at a scale of 1:5,000 – 1:10,000. The slight variation results from the resolution of the individual photographs and features. If the scale is too fine, the features become pixilated and blurry resulting in the necessity to zoom out and broaden the scale.

Land cover has not changed significantly WMAs during the 64-68 year period being examined in this study. Below is a breakdown of total area in 1937 or 1941 and 2005 for all dominant vegetation types within the three WMAs.

The dominant vegetation types examined at Packsaddle were (1) Mixed Grass, (2) Shinnery Oak, (3) Riparian, and (4) Disturbed (i.e. plowed field and/or agriculture plots; Figure 1). In addition, because this study did not examine the riparian zones along the Canadian River, which forms part of the southern boundary, this area was classified as large river riparian on the maps. Total mixed grass in 1937 covered 35,007,557m^2 (3500 ha), total shinnery oak covered 14,228,537m^2 (1423 ha), total riparian covered 1,884,170m^2 (188 ha), total disturbed areas covered 4,187,430m^2 (419 ha), and the large river riparian area encompassed 7,628,549m^2 (763 ha). In 2005, mixed grass covered 34,932,337m^2 (3493 ha), shinnery oak covered 12,503,631m^2 (1250 ha), riparian covered 3,134,601m^2 (314 ha), disturbed areas covered 4,580,394m^2 (458 ha) and large river riparian covered 7,785,280m^2 (779 ha).

Total mixed grass decreased slightly by 0.01% (7 ha), while shinnery oak decreased by 12% (173 ha). The larger decrease in shinnery oak could be a result of fire management that resulted in 1735 hectares (of which 1073 hectares were within areas dominated by shinnery oak) being burned in 2004 and 2005. Total disturbed areas have increased by 8% (39 ha); this can be attributed to the areas that are managed for recreational activities, primarily camping and hunting, as well as areas that are plowed and/or cultivated for ranching and agriculture. Riparian areas have experienced the greatest increase at 40% (126 ha). This could be attributed to the overall increase in precipitation in western Oklahoma since the mid-1980's (OCS 2007).

The dominant vegetation types at Cooper were (1) Sand Sagebrush and Mixed Grass, (2) Riparian and (3) Disturbed (Figure 2). Total sand sagebrush and mixed grass in 1937 covered 63,149,850m^2 (6315 ha) and riparian areas covered 3,251,142m^2 (325 ha). Sand sagebrush and mixed grass are included together for analysis because the quality of the aerial photographs didn't allow for a concrete distinction between the two vegetation types. No disturbed areas were found on this WMA in 1937. This could be attributed to the fact that historically this area remained in possession of one family, rather than being partitioned into multiple land allotments. In 2005, sand sagebrush and mixed grass covered 59,801,211m^2 (5980 ha), riparian covered 6,080,696m^2 (608 ha) and disturbed areas covered 549,084m^2 (55 ha).

Total sand sagebrush and mixed grass decreased by 5% (335 ha) while areas developed/disturbed for agriculture and ranching total 55 hectares. As with Packsaddle, riparian areas have experienced the greatest change by increasing 47% (283 ha). Again, an increase in precipitation form the mid-1980's through the early 2000's could be responsible for this increase.

The dominant vegetation types at Sandy Sanders were (1) Mixed Grass, (2) Mixed Grass, Mesquite and Juniper, (3) Juniper and Mixed Grass, (4) Riparian and (5) Disturbed (Figure 3). In 1941, mixed grass covered 3,745,705m^2 (375 ha), mixed grass, mesquite and juniper covered 59,824,654m^2 (5983 ha), riparian covered 9,360,720m^2 (936 ha) and disturbed areas covered

2,568,935m^2 (257 ha). In 2005, mixed grass covered 6,888,230m^2 (689 ha), mixed grass and mesquite covered 43,576,054m^2 (4358 ha),
juniper and mixed grass covered 11,048,363m^2 (1105 ha), riparian covers 12,790,333m^2 (1279 ha) and disturbed areas covered 1,197,033m^2 (120 ha).

Total mixed grass increased by 46% (314 ha), while areas dominated by a mixture of mixed grass, mesquite and juniper decreased by 9% (520 ha). As many of the areas experiencing increases in mixed grass occur in areas that were disturbed in 1941, a clear correlation can be deduced that mixed grasses establish themselves faster than woody species. In addition, although current vegetation patterns can be visually verified, due to the quality of the historic aerial photographs, the extent of mesquite and juniper in 1941 is difficult to ascertain. As with the other WMA's, riparian areas experienced an increase of 27% (343 ha).

The most consistent land cover change occurring within the three WMA's is an increase in riparian areas. With the historic photographs being taken in 1937 and 1941, it is understandable that riparian areas were more sparsely vegetated in the earlier period. The 1930's was an extremely dry decade that followed two decades of more years totaling below average conditions than those totaling above average conditions (OCS, 2007). In addition, the 1980's and 1990's experienced consistently above average precipitation (OCS, 2007).

Section 2 - Avian Assemblages in Cooper, Packsaddle, and Sandy Sanders Wildlife Management Areas Relative to Shrub Cover.

In shrublands and grasslands, vegetation change is often accompanied by faunal turnover that involves declining abundance of grassland obligate species and increasing abundance of more cosmopolitan species (DeSante & George 1994). The mechanisms by which these changes in abundance occur can be both direct (e.g., increased predation and competition) and indirect (changing microclimates). It is logistically difficult to document specific mechanisms of decline or increase for each member of an assemblage that is in transition, however it is possible to examine the spatial covariation in abundance among species in an assemblage and infer the predominant mechanisms that drive faunal turnover.

Extinction and extirpation of grassland and shrubland-adapted species have been associated with rapid environmental change over the past century (DeSante & George 1994). Appropriately, much of the attention paid to grassland-obligate and shrubland birds has focused on land loss to alternative land uses (Boren et al. 1999), fragmentation (Coppedge et al. 2001), shrub encroachment (Coppedge et al. 2006) and desertification (Van Auken 2000) in remaining grasslands. Separating the effects of habitat loss from those of fragmentation and degradation of remaining habitats is difficult. Combined, these effects have made birds adapted to arid grasslands and shrublands among the fastest declining North American breeding birds (Coppedge et al. 2006; Helzer & Jelinski 1999; Winter et al. 2000).

Understanding the spatial covariation among mixed-grass prairie birds may be helpful in inferring mechanisms causing declines in some guilds (i.e., grassland birds). For example if species with stable populations do not generally co-occur with species whose abundance is declining then either (1) the declining species have been competitive excluded by stable species or (2) these species are selecting entirely different areas; which points to habitat-based mechanisms of decline. In either of these cases there would be limited active behavioral interaction between individuals of stable and declining species (Figure 4 left). However, if stable species co-occur with declining species, then the ongoing behavioral interactions (territorial disputes, predation, scramble competition) may be directly influencing declining trends (Figure 4 middle). It is also possible that no discernible patterns of co-occurrence are evident in avian assemblages.

To examine these patterns of co-occurrence, we counted birds using point methodology on the wildlife management areas. Then we examine spatial covariation in the richness of species with stable population trends and those that are in decline. We use these analyses to understand whether ongoing behavioral interactions are a plausible cause of population declining among grassland and shrubland birds. We conducted separate analyses for grassland and shrubland birds. Finally, we also use the relationship between an index of shrub cover and richness of grassland and shrubland species within each Wildlife Management Area

Methods

Survey Method

We quantified breeding bird assemblages within the WMAs using point counts (Ralph et al. 1993). Surveys were conducted between 0600 and 1000 hours Central Daylight Time (CDT) on days without rain or sustained winds over 20 km/hour as measured with a Kestrel 3000® pocket wind meter. During point counts we recorded all birds seen or heard at each site for 10 minutes. Point locations were recorded using a Garmin® GPS 12. Point counts were at least 600 m apart and were treated as independent observations (Figure 5).

Breeding birds were counted at 51 points at Cooper WMA and 20 points at Packsaddle WMA during the 2006 field season between 15 May and 25 July by J. S. McConnell. LAN counted breeding birds at 70 points at Sandy Sanders WMA and 30 points at Packsaddle WMA between 25 May and 2 July 2007. All point count locations were surveyed at least two times between May and July. To minimize the impact of seasonal and temporal variation, we limited analysis to point counts conducted between 16 June and 2 July (n=171).

Analysis

We used Breeding Bird Survey (BBS) population trends between 1980 and 2006 (Sauer et al. 2007) to classify species as: (1) increasing, (2) declining, or (3) stable. We categorized species as "increasing" or "declining" if the P-value associated with their population trend was less than 0.10 (Sauer et al. 2007). We chose to analyze species trends in the Rolling Red Plains (RRP) physiographic region (Agriculture & Service. 1981). The RRP encompasses western Oklahoma and extends south to the Edwards Plateau in Texas, ensuring species trends are appropriate for the populations residing at each WMA. We also noted species where BBS data within the RRP had data deficiencies resulting in poor regional credibility measures (Sauer et al. 2007) . For these species we used population trends from the Fish and Wildlife Service Region 2, which more broadly covers Oklahoma, Texas, New Mexico and Arizona.

Additionally, we analyzed data by grouping species using habitat guilds defined by Sauer (2007). For species whose guild was not defined by Sauer (2007), we used natural history information to assign them to the most appropriate guild (Appendix 1).

We grouped species with increasing trends with those having no trend because so few species had increasing population trends; hereafter, we refer to this portion of the avifauna as stable species. Measures of richness, abundance and diversity (Shannon-Weiner index) were highly correlated ($r>0.74$), so we primarily used richness as our response variable. We calculated Pearson's product moment correlations using SPSS (SPSS for Windows 2007) to examine associations between species richness of declining and stable species. We also examined patterns in bird species richness between wildlife management area when grouping species by population trend (*i.e.* declining and stable population trends) and habitat guilds.

Avian detections on point counts at both Cooper and Sandy Sanders WMAs peaked at 75 m. The distance to the modal detection distance at Packsaddle WMA was slightly higher at around 150 m. Consequently, we used ArcMap 9.2 to view aerial photographs taken in 2005 to calculate percent shrub coverage within 75 m of each point count location. At each point I digitized the aerial coverage for shrub cover and then divided the total area of these shrubs by the area of the circle. I correlated this percent shrub cover measurement with the richness of both declining and non-declining species, as well as avian richness by habitat guilds.

Results

Bird Diversity

Overall we detected 85 species of birds during fieldwork on the 3 wildlife management areas. We omitted 25 species from further analyses because they were detected only outside of the 16 June and 2 July time window, were only detected flying over, were obligate aquatic species, or were only heard or seen at long distances (>300 m) from count stations. Of the 60 species we analyzed, 8 were grassland and 23 species were shrubland birds, which together comprised 77.2 % of all individuals observed (n=1940). The 29 species we categorized as urban, wetland, and woodland habitat guilds comprised the remaining 22.8% (n=442) of the individuals observed (Appendix 1). Grassland birds accounted for 22.4% of observations and 26.1% of declining species among the three wildlife management areas, and only 5.4% of the stable species. The most common of these declining grassland birds were eastern meadowlark (*Sturnella magna*; n=104), western meadowlark (*Sturnella neglecta*; n=67), and grasshopper sparrow (*Ammodramus savannarum*; n=17).

No bird species was detected on > 50% of point counts at all three sites; however, the brown-headed cowbird (*Molothrus ater*) was observed on > 40% of point counts within each WMA. Of the 10 species observed on > 40% of all point counts, Packsaddle had the most declining species (62.5%, 5 of 8 species) when compared to Cooper (50%, 2 of 4 species) and Sandy Sanders

(40%, 2 of 5 species). Of the 10 species observed on > 40% of point counts in any single WMA, 3 were grassland birds, and 6 were shrubland birds, and 1 was an urban species.

The most abundant species varied among the three WMAs (Appendix 1). Of the 10 most abundant species, only Cassin's sparrow (*Aimophila cassinii; Tier II*) and painted bunting (*Passerina ciris; Tier II*) were not common at all three sites. Overall the 5 most abundant species were brown-headed cowbird (n=177), lark sparrow (*Chondestes grammacus*; n=159), field sparrow (*Spizella pusilla;* n=158), dickcissel (*Spiza americana*; n=146), and northern bobwhite (*Colinus virginianus; Tier III* (n=141). There were 30 species detected 10 or fewer times overall, including the loggerhead shrike (*Lanius ludovicianus*; Tier I, n=4).

We observed the most species (n=47) and individuals (718) at Packsaddle WMA(Table 4). Cooper WMA had higher species richness (n=45) than Sandy Sanders WMA (n=34), however we observed more individuals at Sandy Sanders WMA (n=623) than Cooper WMA (n=599).

Population Trends by Habitat Guilds

Avian species richness was positively correlated with percent shrub cover (r=0.236, P=0.002). Grassland birds exhibited a decline in abundance ($r = -0.294$, $P < 0.001$; Figure 6) and richness (Table 5) as percent shrub cover increased, which is consistent with previous literature; although the same effect is not strong enough at the scale of an individual wildlife management area, a negative trend is consistent between sites. Shrubland species richness increases with percent shrub cover at Cooper and Packsaddle WMAs; Sandy Sanders also has a positive association, although it is not significant (Table 5).

Breeding Bird Survey Population Trends

Declining species richness had no association with percent shrub cover overall at each wildlife management area, although the overall trend was positive (Table 5). Conversely, species richness of non-declining birds increased as percent shrub cover increased at Cooper WMA and overall.

The fractions of species with declining and non-declining BBS trends were similar among the three wildlife management areas (Table 4). At Cooper WMA, the richness of declining and stable species counted per point were highly positively correlated (r=0.580, p>0.001). Packsaddle WMA has the same trend, however the correlation was not as strong (r=0.373; p=0.008). There was no association between the richness of the declining and stable portions of the avian assemblage at Sandy Sanders WMA (Figure 7). Richness of non-declining species among point counts was more variable at Cooper and Packsaddle than at Sandy Sanders, where declining and stable species richness never exceeded seven species per point. Richness of declining species was consistent among WMAs; however both Cooper and Packsaddle had a larger range of richness among declining species. Shrubland species, such as the lark sparrow, field sparrow, and northern bobwhite accounted for 54.0% of the observations for declining species during my surveys, and only 21.7% of all declining species detected (Table 6).

Shrub Cover

Cooper WMA differed significantly from Packsaddle and Sandy Sanders in percent shrub cover, but Packsaddle and Sandy Sanders did not differ ($F=31.311$, $df=2$, $P<0.001$). Shrub cover varied from 0% to 81% overall by plot, and was greater on average at Sandy Sanders and Packsaddle WMAs than at Cooper WMA, while vegetation at Packsaddle WMA was the most variable (Figure 8). At Cooper WMA, 62.7% of all plots had less than 10% shrub cover, while only 15% and 6% of plots at Packsaddle and Sandy Sanders WMAs respectively had < 10% shrub cover. At both Packsaddle and Sandy Sanders WMAs, 50% of all plots had >30% shrub cover, but only 8% of plots at Cooper WMA had > 30% shrub cover

Discussion

Grassland and shrubland birds are declining in North America (Coppedge et al. 2004; Knopf 1994; Vickery et al. 1999; With et al. 2008) and Breeding Bird Survey data indicate the same trend within the Rolling Red Plains bird conservation region. Our data show a negative correlation between shrub cover and grassland bird richness, and a contrasting positive correlation between shrub cover and shrubland bird richness. Additionally, there tend to be more declining species at sites with more percent shrub cover (Table 5).

Several plausible mechanisms could be driving these patterns (Figure 4). In particular the possibility that strong behavioral interaction over limited resources such as nest site selection, territory quality or refugia from predators or adverse environmental conditions. Both Cooper and Packsaddle exhibit the same positive correlation between richness of stable species and those in decline; this correlation suggests that the best habitats for both declining and stable bird species are in the same areas in remaining intact grasslands. At Sandy Sanders, richness of stable birds was lower than at Cooper and Packsaddle WMAs.

Shrub encroachment alters avian assemblages in grasslands (Knopf 1994; Pidgeon et al. 2001). In the mixed-grass prairie, grassland birds have been negatively impacted by shrub encroachment; however, some of the most abundant species associated with successional scrub habitat such as the lark sparrow and northern bobwhite (Tier III) are also suffering declines in areas characterized by woody plant invasion. Coppedge et al. (2004) have shown that encroachment of eastern redcedar (*Juniperus virginiana*) has contributed to declines of both shrubland and grassland birds within mixed-grass prairies of the central United States.

Our data indicate that in Cooper, Packsaddle, and Sandy Sanders WMAs, avian species richness is greater in shrubby areas than those that have less shrub cover. The breeding bird community of the Chihuahuan desert in New Mexico also showed increased species richness in response to habitat conversion from desert grassland to shrubland (Pidgeon et al. 2001). Even though shrubby habitat is not optimal for grassland birds (Pidgeon et al. 2001), there can be high diversity of cosmopolitan species within these landscapes. Increased heterogeneity within these grassland-shrubland mosaic habitats may also contribute to avian species richness (Fuhlendorf et al. 2006).

However, even though percent shrub cover between Packsaddle and Sandy Sanders WMAs was similar ($p = 0.983$ Tukey), species richness differed between these sites ($p < 0.001$ Tukey). This is likely due to differences in the dominant shrubs among sites. Motts of shinnery oak and sand sage dominate the shrub cover at Packsaddle, whereas at Sandy Sanders honey mesquite and redberry juniper are the most abundant shrubs. Our data are consistent with the notion that juniper encroachment has the most deleterious effect on grassland species as suggested by Coppedge et al. (2004).

As suggested by correlations between declining and stable portions of the avian assemblage for each wildlife management area (Figure 6), preserving large tracts of native habitat may be more important than the details species specific conservation plans for a particular grassland or shrubland. Specifically, indiscriminant shrub removal could potentially reduce species richness due to the reduction of habitat heterogeneity, and contribute to the declines of birds of conservation concern such as the bell's vireo (*Vireo bellii*), which reside in these more shrubby habitats. We suggest a fine grained approach to shrub removal that considers the importance of native shrubs such as sand sage and sand plum (*Prunus angustifolia*) to both grassland and shrubland birds for shelter and food, and only reduce cover by shrubs if they become disproportionately more abundant than they were historically, as is true for eastern redcedar and redberry juniper.

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Table 1. Percent cover of all plants encountered at Sandy Sanders Wildlife Management Area.

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16
Ambrosia artemisiifolia	2.29	4	0	0	1.25	0.54	0.5	25	3.5	4.88	12.46	3.63	0	0.5	1.5	0.5
Amphiachyris dracunucloides	1.34	0.5	0.5	25	10.5	6.88	15	15	3.04	10.42	5.09	4.63	0	1	15.5	4
Andropogon gerardii	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia ludoviciana	1.04	0.5	0	0	1.04	2.17	10	1	0	0	4.84	0.92	0	80	0	0
Aristida purpurea	3.92	0	0	0	6.88	18.54	0	0	0.21	0.21	0	1.84	3.71	5	4	20
Asclepias sp.	0	0	0.5	1	0	0	0	0.5	0	0	0	0	0	0	0	0
Astragalus missouriensis	0.04	0	0.5	0.5	0.09	0	0	0	0.04	0.09	0.04	0	0	0	0	0
Bothriochloa ischaemum	0	0	45	0	0	0	0	0	0	5.42	2.13	0	0	0	0	0
Bothriochloa sacchroides	0	0.5	0	0	0.04	0.09	0	0.5	0.09	3.75	0	0	0	0.5	0.5	2.5
Bouteloua curtipendula	16.13	0	0	0	3.75	0.42	0.5	2.5	16.25	5.34	0.54	0.5	0.25	1.5	0	10
Bouteloua dactyloides	0	0	0	0	0	0	0	0	1.67	25.67	0	0.13	0	0	0	0
Bouteloua gracilis	0.96	0	0	0	6.25	0	0	3	25.21	0	8.34	6.67	0	0.5	20	2
Bromus catharticus	0	0	0	0	3.38	0	2.5	0.5	0	0	0	0	0	0	0	0
Bromus tectorum	0.5	0.5	0	55	14	11.67	10.5	20	0.21	1.09	9.34	0.92	0	2.5	25	1.5
Callirhoe involucrata	0	0	0	0	2.09	0	0.5	0	0	0	0	0	0	0	0	0
Cenchrus echinatus	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysanthemum leucanthemum	0	0	0	0	0	0	0	0	0.42	0	0	0	0	0.5	0.5	0
Cirsium undlatum	0	1	0.5	0.5	0	0.04	7.5	0	0	0	0	0	0	0	0	1
Conyza canadensis	0	2.5	0	0.5	0.67	0.21	2.5	0	0	0	0.04	0	0	0.5	0	0
Croton texensis	0	0	0	0	0.04	0	0	1	1.09	0	0.04	0	0	0	0	0
Cucurbita foetidissima	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Cylindropuntia tunicata	0.25	0	0	0	0	0	0	0	0	0.84	0	0	0	0	0	0
Digitaria sanguinalis	0.42	0	0	0	0.04	2.05	0	1	0.54	0	0	0	0	0	0	0
Echinocereus pectinatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Elymus ciliaris	0.25	0	0	0.5	7.13	8.04	1	0	0	0	3.21	0	0	0	0	0
Gaillardia pulchella	0	0	0	0	0.25	6.75	0	0	2.3	0	0.04	0.04	0.04	1	1.5	0
Gaillardia suavis	0	0	0.5	0	0	0	0	0	0	0.09	0	0	0	0	0	0
Grindelia papposa	0.5	1	0	2	6	1.88	1.5	5.5	0.04	0.34	1.67	2.63	0	3.5	0.5	1.5
Helianthus annuum	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterotheca subaxillaris	0	0	0	0	0	0.09	0	0	0.13	0	0	0	0	0	0	0
Juniperus monosperma	0	2	0	0	0	0.42	0	0	0	0	0	1.25	0	0	0	0

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Table 1. Continued

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16
Liatris punctata	0.04	0	1	0	0	0	0	0	0	0	0	0	0	0	0.5	1
Linum perenne	0.42	0	0.5	0	0.09	0.63	0	0.5	0.04	0.29	0	0	0	0	0	0
Linum rididum	0.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lupinus albifrons	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monarda punctata	0	0	0	0	0.04	0.13	0.5	0.5	0	0	0.04	0	0	0.5	2	0
Opuntia machrohiza	1.08	0	0	0	0	0	0	0	0.71	0.29	1.34	5.09	0.67	1	0	1
Penstemon cobaea	0.29	0	0	0.5	0	1.38	0.5	0.5	0	0	0	0	0	0.5	0.5	0
Physalis hispida	0	0	1	0	0	0	0	0.5	0	0	0	0	0	0	0	0
Plantago heterophylla	0.34	0	1	1.5	0.63	2.17	1	0	0.04	0	0.17	0.13	0.04	1	1	0
Plantago patagonica	0	0	0	0	0.21	0.04	0	0	0.29	0	0	0	0	0	0	0
Plantago rhodosperma	0	0	0	0	2.88	1.71	0	0.5	0.63	0.04	0.09	0.09	0	0	0.5	0
Prosopis glandulosa	2.59	3.5	6	10	0	1.59	22.5	8	1.46	0	6.41	0.04	0.09	0	5	25
Ratibida columifera	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0
Robinia pseudoacacia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schizachyrium scorparium	5.46	35	35	0	0	0	0	0	0	0	2.09	33.75	20.84	1.5	0	0.5
Solanum elaeagnifolium	0.17	0	1	0	0.08	0.09	0	1	0.25	0.04	0.29	0	0	0.5	1	0
Solidago gigantea	0	0	0	0	0.09	0.25	0	0	0	0	0.04	0	0	0	0	0
Sorghastrum nutans	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelesperma megapotamicum	0	0	0	0	0	0	0	0	0.13	0	0	0.04	0	0	0	0
Tridens flavus	0	0	0	0	0	0.09	0	0	0	0	0	0.79	1.17	0	0	0
Triteleia hyacinthina	0	0	0	0	0.09	0	0	0	0.04	0	0	0	0	0	0	0
Yucca glauca	0	0	0	0	0	0	0	0	0	0	0	0.21	0.38	0	0	0

Table 2. Percent cover by plant species in 16 plots at Packsaddle WMA

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16
Ambrosia artemisiifolia	2.08	2.71	23.75	22.5	0.5	1.5	0.42	0.59	7.5	1.04	35	50	60	47.5	25.71	18.54
Amphiachyris dracunucloides	0	0	0	15.5	0	0	0.13	0	0	0	0	0	0	0	0	0
Andropogon gerardii	4.42	4.88	2.59	0	3	1	2.96	8.04	0	0.83	1.5	4	0	5	0.21	16.25
Argemone polyanthemos	0	0	0.08	1	0	0	0	0	0	0	0	0	0	1	0	0
Aristida purpurea	0	0	0	0	0	0	2.92	0	0	0	0	0	0	1	0	0
Artemisia filifolia	12.8	6.46	9.13	5	0.5	0.5	9.5	0.46	0	0.17	25	10	0	5	17.38	0.09
Artemisia ludoviciana	0.04	0.04	2.84	0	0.5	27.5	2.25	0	0.5	0	20	4	0	2	0	0
Bothriochloa sacchroides	0	0	0	0	0	0	0	0	0.5	0	1	0	0	0	0	0
Bouteloua curtipendula	0.17	0.13	0.46	0	0.5	1	0.3	0.38	1	0	0	0.5	0	0	0	2.63
Bouteloua gracilis	0.38	0.13	0	0	0	0	0.13	0.25	0	0	0	0	0	0.5	2.21	0
Bouteloua hirsuta	0	0	0	0	0	0	0	0.25	0	0	0	0	0	0	0	0
Bromus tectorum	0	0	11.3	0.5	0	8.5	0.09	0	0.5	0	0	0	0.5	1.5	0.42	4.5
Callirhoe involucrata	0	0	0.04	0	0	0	0.09	0	0	0	0.5	0	0	0.5	0	0
Cenchrus echinatus	0	0	0.04	0.5	0	0	0	0	0	0	0.5	0	0.5	0.5	1.34	0
Chloris virgata	0	0.79	0	0.5	0	0	0	1.04	0	0	0.5	0.5	0.5	0.5	0	0
Cirsium undlatum	0	0	0.09	0.5	0	0	0	0	0	0	1	0	0	0	0.09	0.21
Commelina erecta	0.13	0.29	0.25	0	0	0	0.29	0.13	0	0	0.5	0.5	1	0.5	0.09	0.04
Conyza canadensis	0	0	0.17	1	0	7.5	0.59	0	0	0.13	0.5	0	0.5	1	0.09	0.13
Croton texensis	0.04	0.04	0.75	35	0	0.5	0.25	0	0	0	1	0	0	0	1.29	0
Cucurbita foetidissima	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus scheinitz	0.25	0	0	0	0	0	0.09	0	0	0	0.5	0.5	0	0	0	0.09
Dalea enneardra	0	0	0	0	0	0	0	0	0	1.92	0	0	0	0	0	0.04
Dimorphocarpa candicans	0	0	0.04	0	0	0	0	0	0	0	0	0	0.5	0	0	0
Eragrostis secundiflora	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0	0
Eriogonum annuum	0	0	0	0	0	0.5	0	0	0.5	0	0.5	0.5	0.5	0.5	0.29	0.09
Gaillardia pulchella	0	0	0.04	0	0	0	0.17	0.04	0	0	3.5	1	0	0.5	12.25	0.08
Grindelia papposa	0	0	0	1	0	0	0	0	0	0	0	0	0.5	0	0	0.09
Helianthus annuus	0	0	0	5	0.5	0	0	0	0	0	0	0	0	0	0	0
Helianthus petiolaris	0	0	0	10	0	0.5	0	0	0	0	0	0	1	0	0.04	0
Heterotheca subaxillaris	0	0	14.79	1	0	0	0.04	0.04	1	0	0	1	1	1.5	0.04	0.09
Liatris punctata	0.09	0.17	0.17	0	0	7.5	1.29	0	1.5	0	0	0.5	0	0.5	0.17	0.25
Lupinus albifrons	0.04	0.04	0.88	0	1	1	0	0	1	0	1	2.5	1	12.5	0.88	0.13
Monarda punctata	0.29	0.29	0	0	0.5	0	0	0	0	0	1.5	0	0.5	0	0	0
Opuntia machrohiza	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis stricta	0	0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago heterophylla	0	0.34	0.21	0	0	0	0.79	0.17	1	0	1	1	1	1.5	3.84	3.3
Poa arachnifera	0	0	0	0	0	1.5	0.04	0	0	0	0	0	0.5	0	0	0.29
Prunus angustifolia	0	0	0	0	0	0	0	1.55	0	0	0	0	0	0	0	0
Quercus havardii	32	41.05	0.42	0	70	32.5	18.96	9.8	0	0	0	0	0	0	0	0
Ratibida columifera	0	0	0	0	0	0	1.21	0	0	0	1	0	0	0	0	0

Table 2. Continued

Robinia pseudoacacia	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Schizachyrium scorparium	30.83	25	19.09	0	22.5	7.5	13.38	50	2	68.96	6	10	25	5.5	2.25	29.8
Solanum elaeagnifolium	0	0	0.38	0	0	2	0.82	0	0	0	0	0	0	1	0	0
Solidago Gigantea	0	0.09	0	0	0	0	0	0	0.5	0	0	0.5	0.5	0	0	0.04
Sorghastrum nutans	0.09	0.09	0	0	0.5	0	0	0.13	0	0	0.5	1	0	0.5	0	7.84
Tradescantia occidentalis	0.09	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.09	0
Tragia ramosa	1.05	0.38	0.38	0	0	2	0	0.21	0	0	0	1	0.5	0.5	0	0
Tridens flavus	0.09	0.09	0.71	0	0	0	0	0.17	0	0.09	0	0	0	0	0	0.09
Yucca glauca	0	0	0	0	0	0	0	0.84	0	0	0	0	0.5	0	0	0

Table 3. Percent cover by plant species at Cooper WMA

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16
Ambrosia artemisiifolia	21.25	3.88	28	13.88	3.21	12.5	3	18.5	10	6.5	4.79	15	2.75	0.38	1.5	1
Aphanostephus skirrhobasis	0.5	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0.5	0
Artemisia filifolia	9.59	37.75	13.04	29.34	13.13	60	40	10	37.5	65	24.21	50	6.63	29.5	37.5	15
Artemisia ludoviciana	1.25	0.92	0.13	0.09	0.09	2	1	1	0.5	1	0.25	0.5	0.5	0.21	1	1
Bothriochloa sacchroides	0	0	0	0	0	0	0	0	0	0	0	0	0.42	0	0	0
Bouteloua curtipendula					0.17	0	0	0	0	0	1.38	0	0.29	0	0	0
Bouteloua gracilis	18.5	0.88	10.25	1.34	5.04	10	0	5.5	0	0	1.38	1.5	19.67	4.96	0	0
Bromus tectorum	13.75	0	0.42	0	0	0	0.5	10	5.5	0	0	6	9.21	7.71	0	15
Callirhoe involucrata	0.13	0	0.04	0	0	1	0.5	0.5	0.5	0	0	0	0	0	0	0
Cenchrus echinatus	0	0.17	0.17	0.21	0	0.5	0.5	0.5	0.5	0	0.25	0	0.21	0.17	0	1
Chamaesyce missurica	0	0	0.04	0	0.09	0	0	0	0	0	0	0	0	0	0	0
Chloris virgata	0.63	0	0.04	0	0	0	0	0	0	0	0	0	0.17	0	0	0
Cirsium undlatum	0.21	0	0.25	0	0.04	0	1	0	0	0	0.09	0	0.04	0	1	1
Commelina erecta	0	0.38	0.09	0.13	0.25	0.5	0	0.5	1	1	0.34	0.5	0.09	0.88	0.5	0
Conyza canadensis	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0
Croptilon divaricatum	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
Croton texensis	0	0	0.13	0.04	0.04	0.5	0.5	0.5	0	0	0.09	0	0	0	0	0.5
Cucurbita foetidissima	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0
Cyperus scheinitz	0	0	0	0.04	0.04	0	0	0	0	0	0.09	0	0.04	0.04	0	0.5
Eragrostis secundiflora	0	0.46	0	0.34	0	0	0	0	0	0	0.21	0	0.04	0	0	0
Eriogonum annuum	0	0	0.25	0.04	0	0	0	0	0	0	0	0	0.13	0	0.5	0
Euphorbia dentata	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	4.67	0	0
Gaillardia pulchella	1.21	0	0	0	0.13	1	1	0.5	0.5	0.5	0.09	0.5	0.13	0.09	1	0
Gaura coccinca	0	0	0	0	0	0	0	0.5	0	0	0	0	0.17	0	0	0.5
Heterotheca subaxillaris	0.04	0	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0
Indigofera miniata	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0
Juniperus virginiana	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lepidium densiflorum	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mentzelia nuda	0	0.84	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mollugo verticillata	0	0	0	0	0	0	0	0	0	0	2.5	0	0.63	0.21	0	0
Opuntia machrohiza	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	1	0
Oxalis stricta	0	0	0.04	0	0	0	0	0	0	0	0	0	0.09	0	0	0
Panicum virgatum	0	3.59	0.25	0.34	0.04	7.5	1	1	0	0	0.04	2.5	0.04	4.04	0	5
Physalis hispida	0	0	0	0	0	0	0	0.5	0.5	0	0	0.5	0	0.04	0	0
Plantago heterophylla	3.09	0.17	0.67	0	0.92	2.5	1	0.5	2	1	1.38	1	0.38	0.58	0.5	3
Poa arachnifera	0.04	0	0	0	0.09	1	0	1.5	0	0	0	0.5	0	0.5	0	0.5
Prunus angustifolia	0	2.88	0.04	0	2	0	0	0	0	0	1.38	0	0	0	0	0
Rhus aromatica	0	0	0	0	0.04	0	0	0	0	15	0.21	0	0	0	12.5	0
Rhus trilobata	0	0	0	0	2.96	0	0	0	0	0	1.25	0	0	0	0	0
Salvia azurea	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0
Schizachyrium scorparium	0	5.88	25.71	25	20.3	0	50	10.5	30	5	11.92	4	18.88	0.34	40	60
Solanum elaeagnifolium	0.42	0	0.29	0.04	1.5	6.5	1	26	6	0	0	10	1.04	1.54	0	0

Table 3. Continued

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	
Solidago missouriensis	0.29	3.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sporabolus cryptandrus	3.84	0.09	0	0	0.25	0	0	0.5	0	0	0	0	2.59	2.5	0	0.5	
Thelesperma megapotamicum	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	
Tragia ramosa	0	0.04	0	0	0	0	0	0	0.5	0	0	0	0.13	0	0	0	
Tridens flavus	0	0	0.09	0.13	0.13	0	0	0	0	0	0.09	0	0.29	0	0	0	
Yucca glauca	0	1.96	0	1.67	0	0	0	0	0	0	0	0	0	0	0	0	

Table 4–Species richness by BBS trend and habitat guild at Cooper, Packsaddle, Sandy Sanders WMAs in western Oklahoma, and overall.

Species Richness	Overall	Cooper	Packsaddle	Sandy Sanders
By BBS Trend				
Declining	23	18	17	13
Stable	37	27	30	21
By Habitat Guild				
Grassland	8	7	6	3
Shrubland	23	18	20	14

Table 5–Pearson correlation coefficients (r) between % shrub cover and species richness for four categories at Cooper, Packsaddle, Sandy Sanders WMAs in western Oklahoma, and overall. Bolded values are significant at $p < 0.05$.

Species Richness	Overall	Cooper	Packsaddle	Sandy Sanders
By BBS Trend				
Declining	0.122	0.144	0.218	0.043
Non-Declining	**0.258****	**0.574****	0.246	0.065
By Habitat Guild				
Grassland	**-0.284****	-0.041	-0.151	-0.153
Shrubland	**0.421**	**0.480****	**0.462***	0.194

*–P>0.01

**–P>0.001

Table 6–Declining species richness (as defined by BBS trend) by habitat guild at Cooper, Packsaddle, Sandy Sanders WMAs in western Oklahoma, and overall.

Habitat Guild	Overall	Cooper	Packsaddle	Sandy Sanders
Grassland	6	5	4	2
Shrubland	5	4	4	4

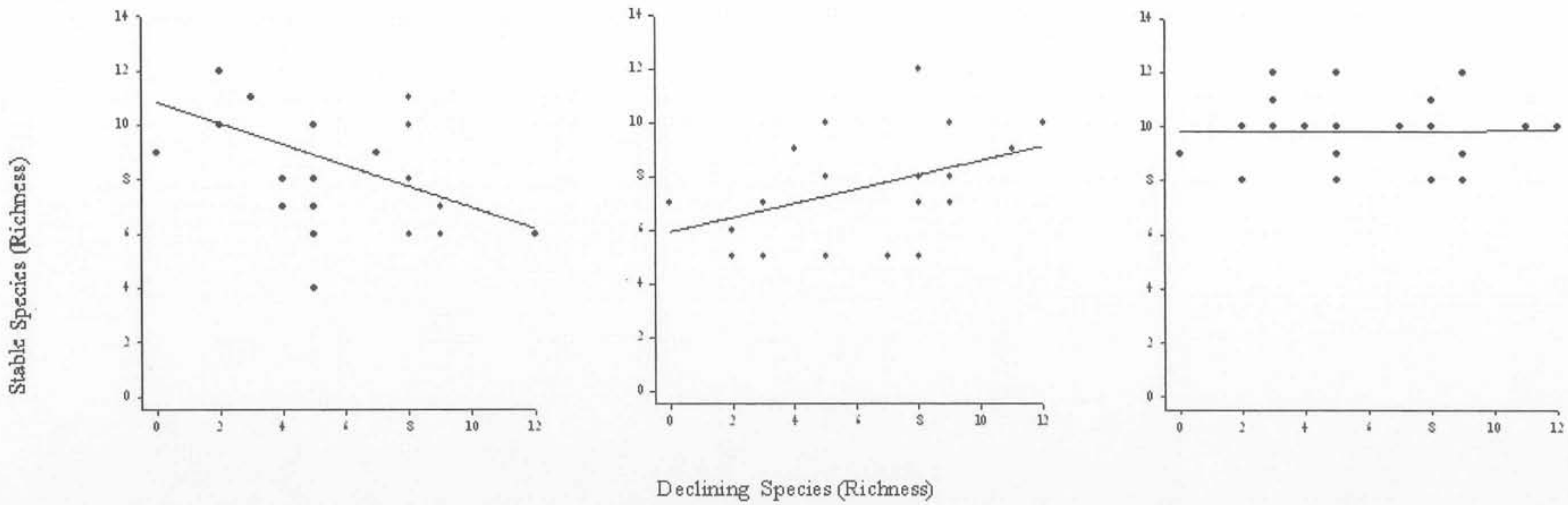

Figure 4—Hypothetical interations between the declining and non-declining (as defined by BBS trend) portions of the avian assemblage associated with faunal turnover in response to shrub proliferation. A negative correlation (a) could indicate declining species are out-competing other species within specific habitats and wildlife managers must conserve the habitat in order to conserve species richness; while a positive correlation (b) suggests overall habitat is good and species specific conservation maybe best. If declining species richness is highly variable compared to the non-declining assemblage whose species richness remains high (c), suitable habitats for declining species may be highly variable, whereas the non-declining species have more available potential habitat.

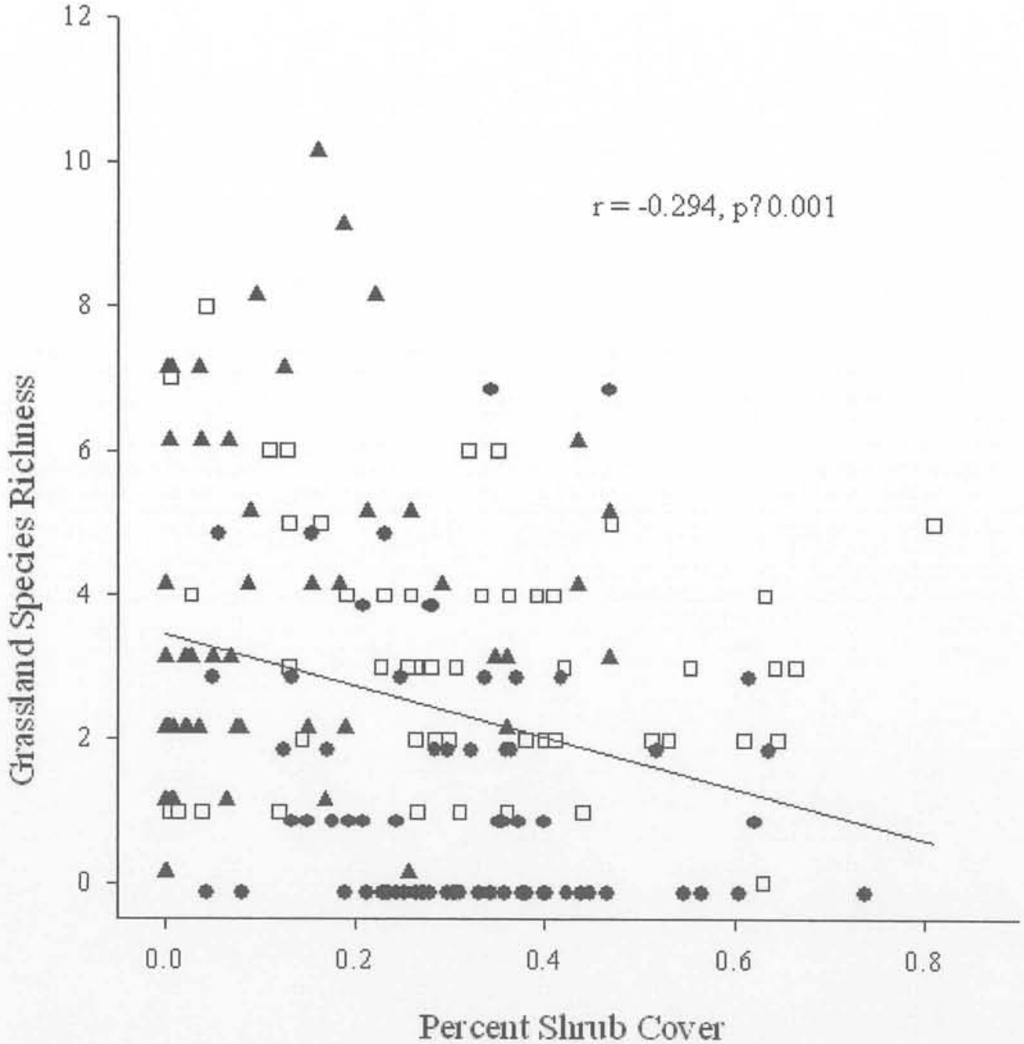

Figure 6—The effect of percent shrub cover on grassland species abundance at Cooper (?), Packsaddle (?) and Sandy Sanders (?) WMAs collectively. Data for Cooper and Sandy Sanders WMAs were slightly shifted so patterns are more distinguishable between the wildlife management areas.

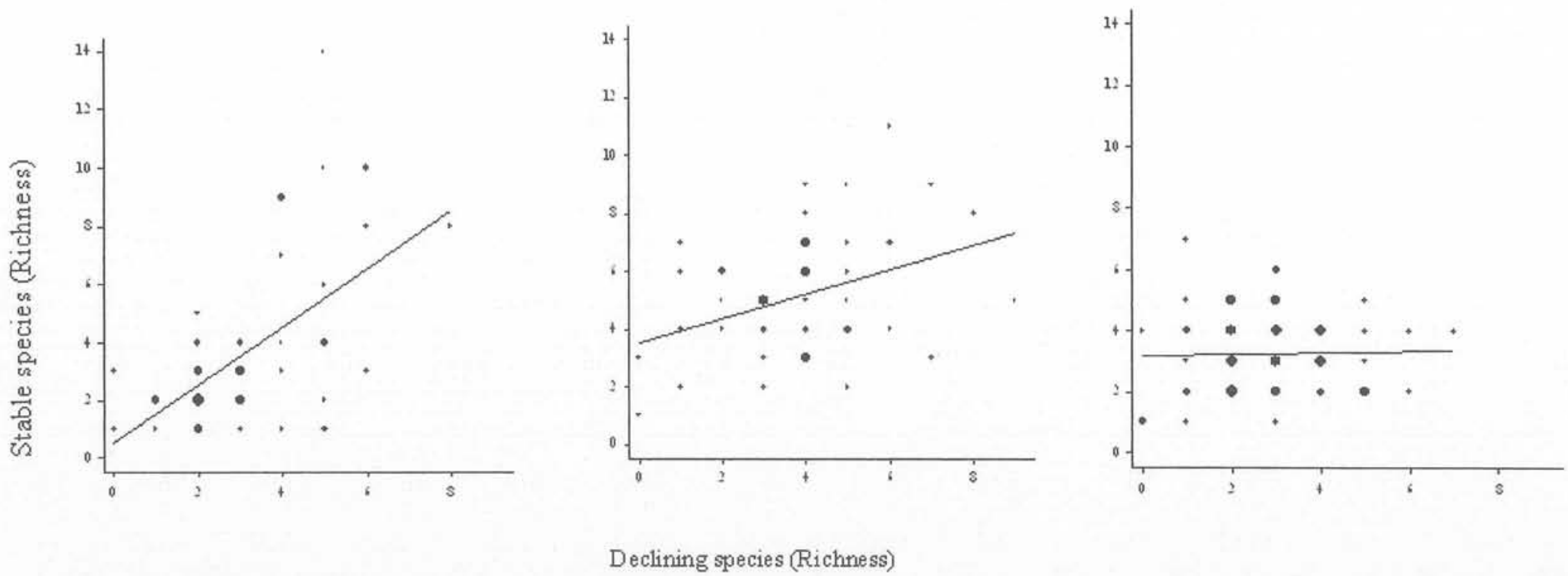

Figure 7—Comparison of declining and non-declining species richness (as defined by BBS trend) for Cooper (a), Packsaddle (b), and Sandy Sanders (c) WMAs. Each point in these scatter plots represents the total species richness observed at a particular point count location. The number of point count locations, ranging from one to four, with equal ratios of declining to non-declining species is reflected in the size of the plot data.

Appendix 1—Total number of individuals observed per bird species[a] within Sandy Sanders, Packsaddle, and Cooper WMAs of western Oklahoma, from 16 June and 2 July of 2006 and 2007, by Breeding Bird Survey population trend for 1980 - 2006. G, Grassland; S, Successional Scrub; U, Urban; We., Wetland; Wo., Woodland. *n*, species abundance by WMA; $\bar{x}$, average number of observations per point count location; SD, standard deviation of observations per point count location. All species in bold were observed at least 20 times throughout the study period by WMA.

		Cooper		Packsaddle		Sandy Sanders	
Declining Species	Guild	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)
Lark Sparrow (*Chondestes grammacus*)	**S**	**29**	**0.569 (1.063)**	**41**	**0.820 (1.395)**	**89**	**1.271 (1.166)**
Field Sparrow (*Spizella pusilla*)	**S**	**65**	**1.275 (1.250)**	**73**	**1.460 (1.199)**	**20**	**0.286 (0.542)**
Northern Bobwhite (*Colinus virginianus*)	**S**	**55**	**1.078 (1.730)**	**62**	**1.240 (1.302)**	**24**	**0.343 (0.535)**
Mourning Dove (*Zenaida macroura*)	**U**	**25**	**0.490 (0.857)**	**47**	**0.959 (1.136)**	**62**	**0.886 (0.956)**
Eastern Meadowlark (*Sturnella magna*)	**G**	**42**	**0.824 (0.910)**	**47**	**0.940 (1.018)**	**15**	**0.214 (0.740)**
Western Meadowlark (*Sturnella neglecta*)	**G**	**35**	**0.686 (1.334)**	**0**	**0**	**32**	**0.457 (0.736)**
Yellow-billed Cuckoo (*Coccyzus americanus*)	Wo.	4	0.078 (0.272)	14	0.280 (0.497)	8	0.114 (0.320)
Grasshopper Sparrow (*Ammodramus savannarum*)	G	10	0.196 (0.448)	7	0.140 (0.351)	0	0
Rufous-crowned Sparrow (*Aimophila ruficeps*)	S	0	0	0	0	17	0.243 (0.464)

Appendix 1 continued

		Cooper		Packsaddle		Sandy Sanders	
Declining Species	Guild	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)
Common Grackle (*Quiscalus quiscula*)	U	1	0.020 (0.140)	1	0.020 (0.141)	8	0.114 (0.401)
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	Wo.	3	0.059 (0.238)	4	0.080 (0.444)	1	0.014 (0.120)
Downy Woodpecker (*Picoides pubescens*)	Wo.	3	0.059 (0.238)	4	0.080 (0.340)	0	0
Northern Flicker (*Colaptes auratus*)	Wo.	0	0	5	0.100 (0.505)	2	0.029 (0.168)
Eastern Kingbird (*Tyrannus tyrannus*)	G	1	0.020 (0.140)	4	0.080 (0.274)	0	0
Killdeer (*Charadrius vociferus*)	U	1	0.020 (0.140)	0	0	4	0.057 (0.376)
Mississippi Kite (*Ictinia mississippiensis*)	S	2	0.039 (0.196)	3	0.060 (0.240)	0	0
Barn Swallow (*Hirundo rustica*)	U	0	0	4	0.080 (0.566)	0	0
Black-capped Chickadee (*Poecile atricapillus*)	Wo.	0	0	3	0.060 (0.240)	1	0.014 (0.120)
Loggerhead Shrike (*Lanius ludovicianus*)	G	4	0.078 (0.337)	0	0	0	0
Green Heron (*Butorides virescens*)	We.	1	0.020(0.140)	2	0.040 (0.198)	0	0

Appendix 1 continued

		Cooper		Packsaddle		Sandy Sanders	
Declining Species	Guild	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)
Western Kingbird (*Tyrannus verticalis*)	G	0	0	2	0.040 (0.283)	0	0
Belted Kingfisher (*Ceryle alcyon*)	We.	1	0.020 (0.140)	0	0	0	0
Chuck-will's-widow (*Caprimulgus carolinensis*)	Wo.	1	0.020 (0.140)	0	0	0	0
Increasing Species							
Northern Mockingbird (*Mimus polyglottos*)	**U**	**34**	**0.667 (1.143)**	**18**	**0.360 (0.631)**	**10**	**0.143 (0.352)**
Red-bellied Woodpecker (*Melanerpes carolinus*)	Wo.	6	0.118 (0.325)	9	0.180 (0.438)	3	0.043 (0.204)
Eastern Bluebird (*Sialia sialis*)	S	6	0.118 (0.588)	9	0.180 (0.774)	0	0
Cliff Swallow (*Petrochelidon pyrrhonota*)	We.	1	0.020 (0.140)	6	0.120 (0.718)	0	0
Tufted Titmouse (*Baeolophus bicolor*)	Wo.	0	0	0	0	4	0.057 (0.478)
Ash-throated Flycatcher (*Myiarchus cinerascens*)	S	0	0	0	0	3	0.043 (0.204)
Song Sparrow (*Melospiza melodia*)	S	0	0	1	0.020 (0.141)	2	0.029 (0.168)

Appendix 1 continued

		Cooper		Packsaddle		Sandy Sanders	
Increasing Species	Guild	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)
Carolina Wren (*Thryothorus ludovicianus*)	S	2	0.039 (0.196)	0	0	0	0
Eastern Phoebe (*Sayornis phoebe*)	Wo.	0	0	0	0	2	0.029 (0.168)
American Goldfinch (*Carduelis tristis*)	S	0	0	1	0.020 (0.141)	0	0
Stable Species							
Brown-headed Cowbird (*Molothrus ater*)	**S**	**76**	**1.490 (1.447)**	**61**	**1.220 (1.569)**	**40**	**0.571 (0.827)**
Dickcissel (*Spiza americana*)	**G**	**20**	**0.392 (0.802)**	**80**	**1.600 (1.443)**	**46**	**0.657 (0.946)**
Painted Bunting (*Passerina ciris*)	**S**	**9**	**0.176 (0.434)**	**21**	**0.420 (0.575)**	**87**	**1.243 (0.908)**
Northern Cardinal (*Cardinalis cardinalis*)	**S**	**20**	**0.392 (0.850)**	**30**	**0.600 (0.833)**	**54**	**0.771 (0.871)**
Cassin's Sparrow (*Aimophila cassinii*)	**G**	**74**	**1.451 (1.205)**	**16**	**0.320 (0.868)**	**0**	**0**
Bewick's Wren (*Thryomanes bewickii*)	**S**	**3**	**0.059 (0.238)**	**20**	**0.400 (0.606)**	**22**	**0.314 (0.553)**
Scissor-tailed Flycatcher (*Tyrannus forficatus*)	S	2	0.039 (0.196)	15	0.300 (0.763)	15	0.214 (0.587)

Appendix 1 continued

Stable Species	Guild	Cooper		Packsaddle		Sandy Sanders	
		n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)
American Crow (*Corvus brachyrhynchos*)	Wo.	7	0.137 (0.448)	17	0.340 (0.872)	6	0.086 (0.282)
Wild Turkey (*Meleagris gallopavo*)	Wo.	0	0	2	0.038 (0.194)	19	0.271 (2.035)
Bell's Vireo (*Vireo bellii*)	S	5	0.098 (0.361)	14	0.280 (0.536)	1	0.014 (0.120)
Blue Grosbeak (*Passerina caerulea*)	S	6	0.118 (0.382)	12	0.240 (0.476)	2	0.029 (0.168)
Blue-gray Gnatcatcher (*Polioptila caerulea*)	Wo.	5	0.098 (0.300)	14	0.280 (0.607)	0	0
Brown Thrasher (*Toxostoma rufum*)	S	3	0.059 (0.238)	11	0.220 (0.465)	2	0.029 (0.168)
Red-winged Blackbird (*Agelaius phoeniceus*)	We.	3	0.059 (0.238)	4	0.080 (0.274)	8	0.114 (0.468)
Great Crested Flycatcher (*Myiarchus crinitus*)	Wo.	3	0.059 (0.238)	10	0.200 (0.495)	1	0.014 (0.120)
Carolina Chickadee (*Poecile carolinensis*)	Wo.	7	0.137 (0.530)	5	0.100 (0.303)	0	0
Common Nighthawk (*Chordeiles minor*)	U	0	0	2	0.040 (0.198)	8	0.114 (0.468)
Ring-necked Pheasant (*Phasianus colchicus*)	S	6	0.118 (0.325)	2	0.040 (0.198)	0	0

Appendix 1 continued

Stable Species	Guild	Cooper *n*	Cooper $\bar{x}$ (SD)	Packsaddle *n*	Packsaddle $\bar{x}$ (SD)	Sandy Sanders *n*	Sandy Sanders $\bar{x}$ (SD)
Red-tailed Hawk (*Buteo jamaicensis*)	S	6	0.118 (0.382)	2	0.040 (0.198)	0	0
Greater Roadrunner (*Geococcyx californianus*)	S	2	0.039 (0.196)	4	0.080 (0.340)	0	0
Blue Jay (*Cyanocitta cristata*)	U	0	0	0	0	5	0.071 (0.393)
Warbling Vireo (*Vireo gilvus*)	Wo.	4	0.078 (0.272)	1	0.020 (0.141)	0	0
Indigo Bunting (*Passerina cyanea*)	S	2	0.039 (0.196)	2	0.040 (0.198)	0	0
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	We.	0	0	4	0.080 (0.340)	0	0
Rock Pigeon (*Columba livia*)	U	3	0.059 (0.420)	0	0	0	0
Common Yellowthroat (*Geothlypis trichas*)	S	0	0	2	0.040 (0.198)	0	0
Great Horned Owl (*Bubo virginianus*)	Wo.	1	0.020 (0.140)	0	0	0	0

A - species excluded from analysis – American Kestrel (*Falco sparverius*), Barred Owl (*Strix varia*), Clay-colored Sparrow (*Spizella pallida*), Chipping Sparrow (*Spizella passerina*), Chimney Swift (*Chaetura pelagica*), Eastern Wood-pewee (*Contopus virens*), European Starling (*Sturnus vulgaris*), Great Blue Heron (*Ardea herodias*), Great-crested Flycatcher (*Myiarchus crinitus*), Hairy Woodpecker (*Picoides villosus*), House Finch (*Carpodacus mexicanus*) , Little Blue Heron (*Egretta caerulea*), Mallard (*Anas platyrhynchos*), Northern Harrier (*Circus cyaneus*), Orchard Oriole (*Icterus spurious*), Pileated Woodpecker (*Dryocopus pileatus*) , Purple Martin (*Progne subis*), Spotted Sandpiper (*Actitis macularia*), Swainson's Hawk (*Buteo swansoni*), Turkey Vulture (*Cathartes aura*), Upland Sandpiper (*Bartramia longicauda*), White-breasted Nuthatch (*Sitta carolinensis*), Wood Duck (*Aix sponsa*)

Significant Deviations: None

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Date: November 24, 2009

Approved by: ______________________

Alan Peoples, Chief, Wildlife Division
Oklahoma Department of Wildlife Conservation

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John D. Stafford, Federal Aid Coordinator
Oklahoma Department of Wildlife Conservation

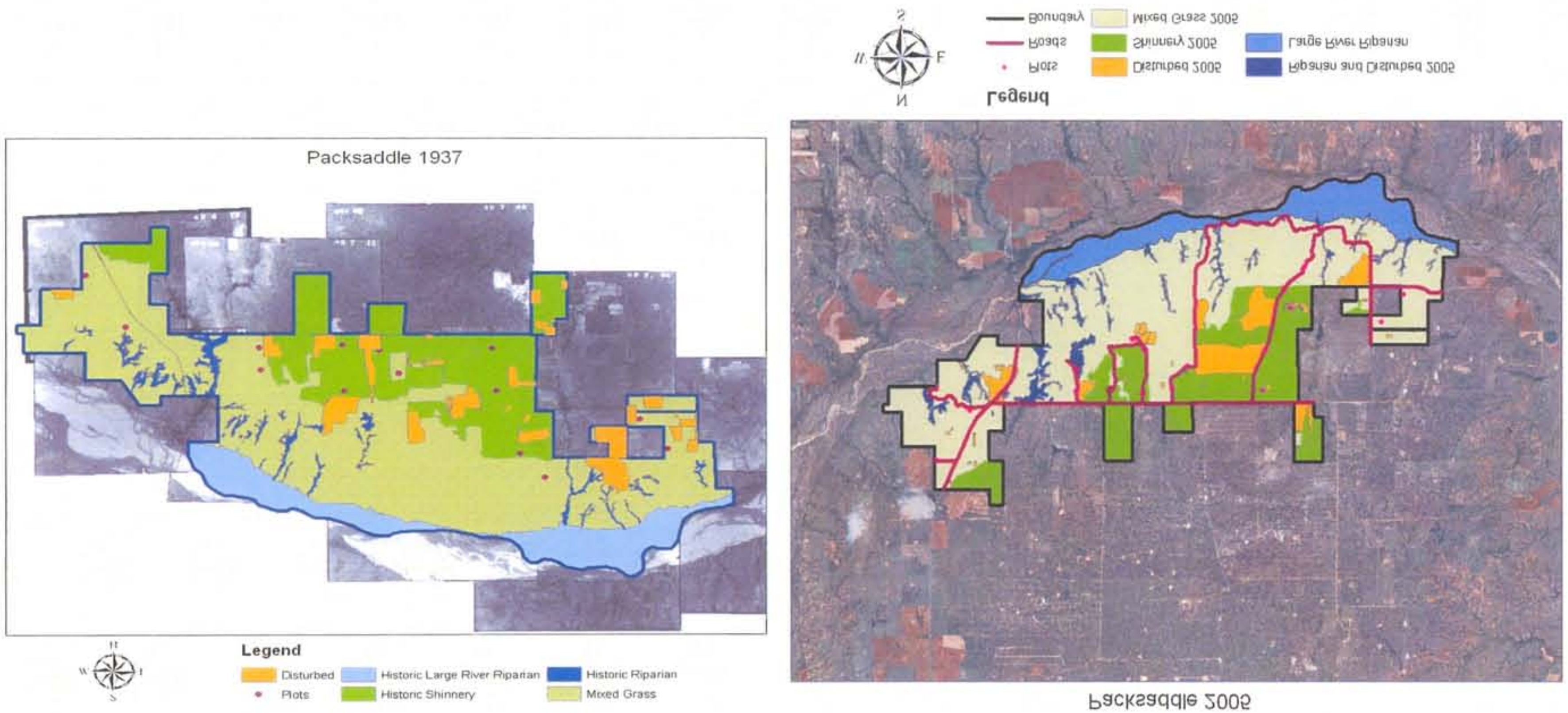

Figure 1. Vegetation in Packsaddle Wildlife Management Area as digitized from Aerial photography from 1937 and 2005.

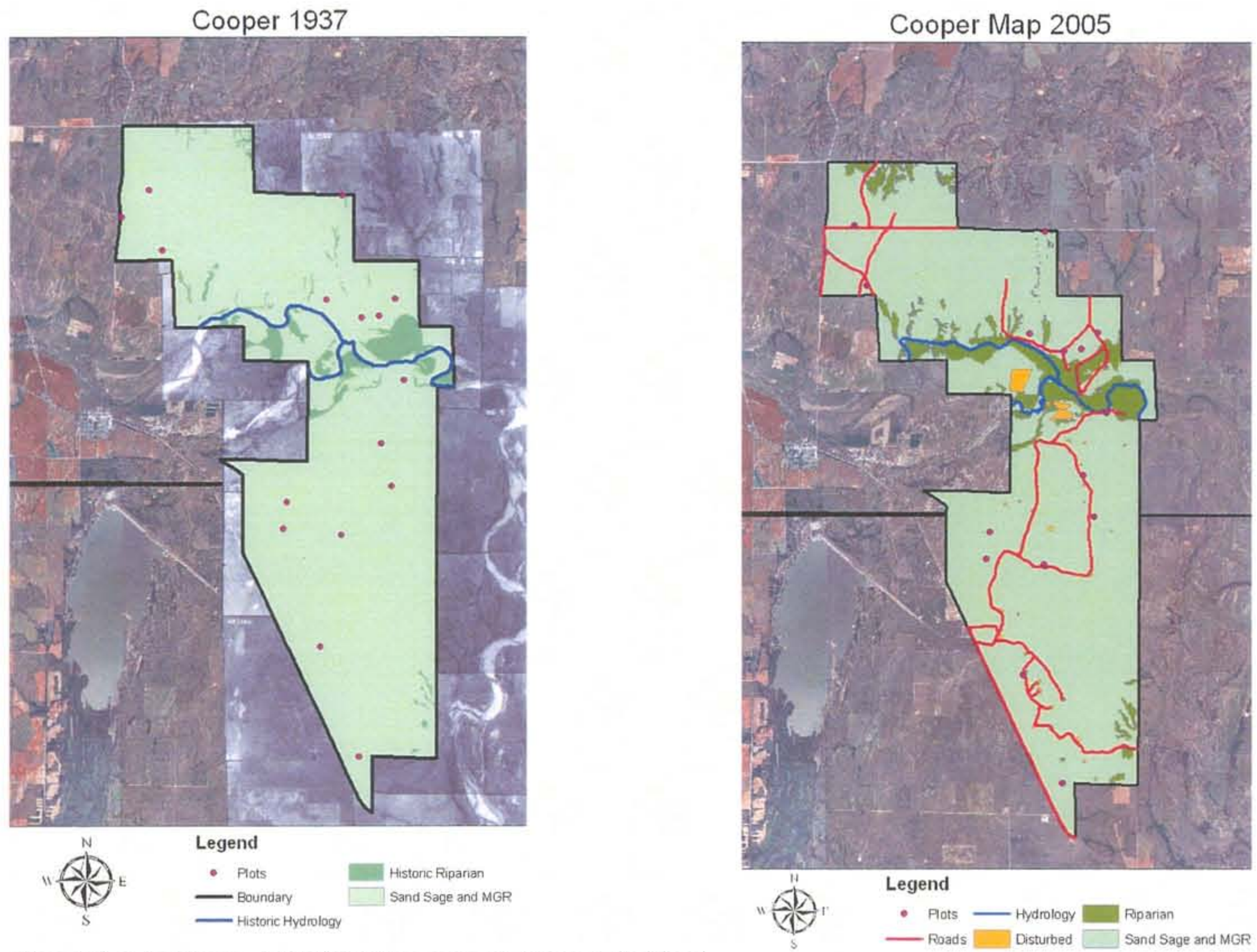

Figure 2. Vegetation in Cooper Wildlife Management Area as digitized from aerial photography from 1937 and 2005.

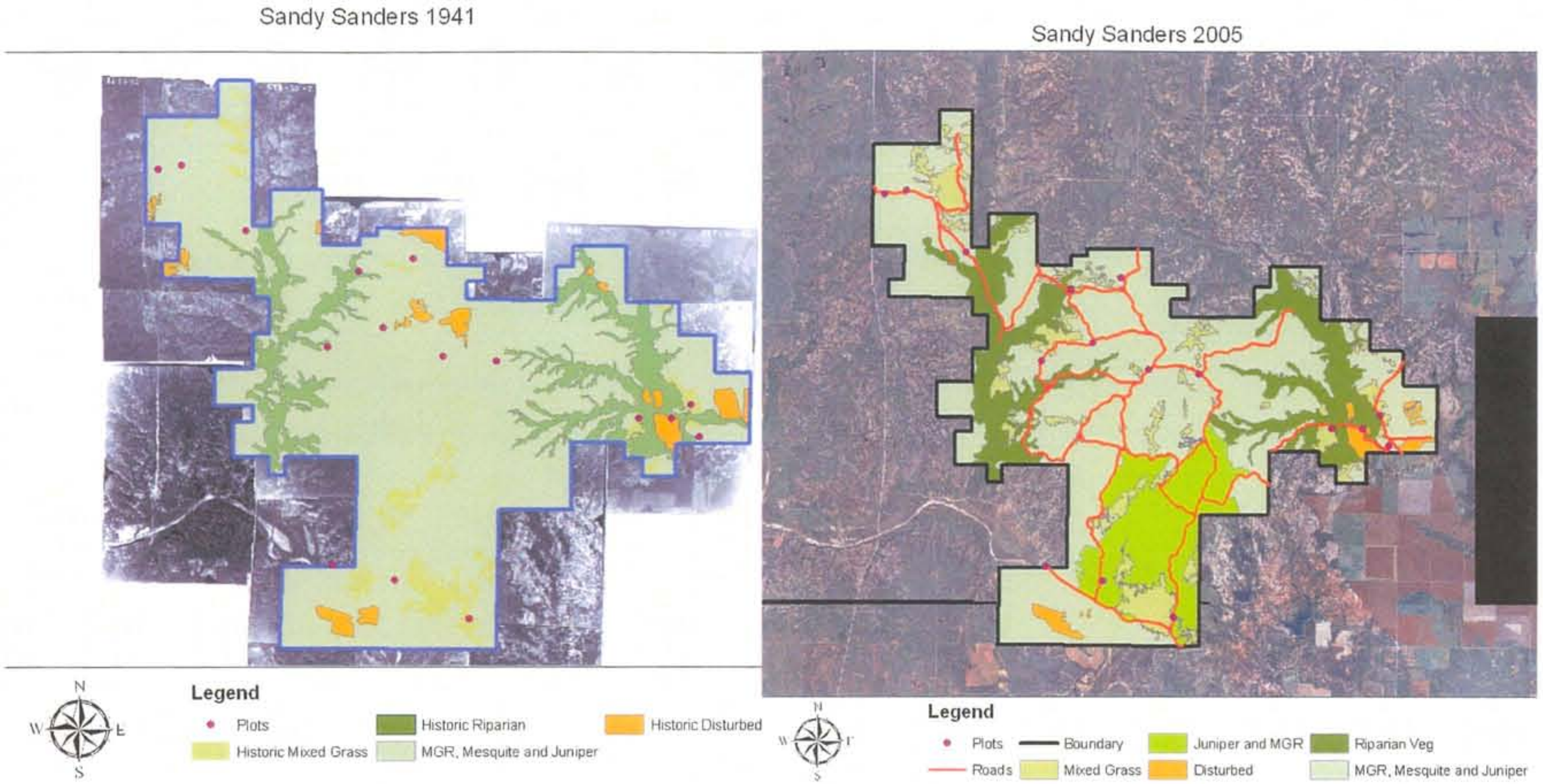

Figure 3. Vegetation in Sandy Sanders Wildlife Management Area as digitized from aerial photography from 1937 and 2005.

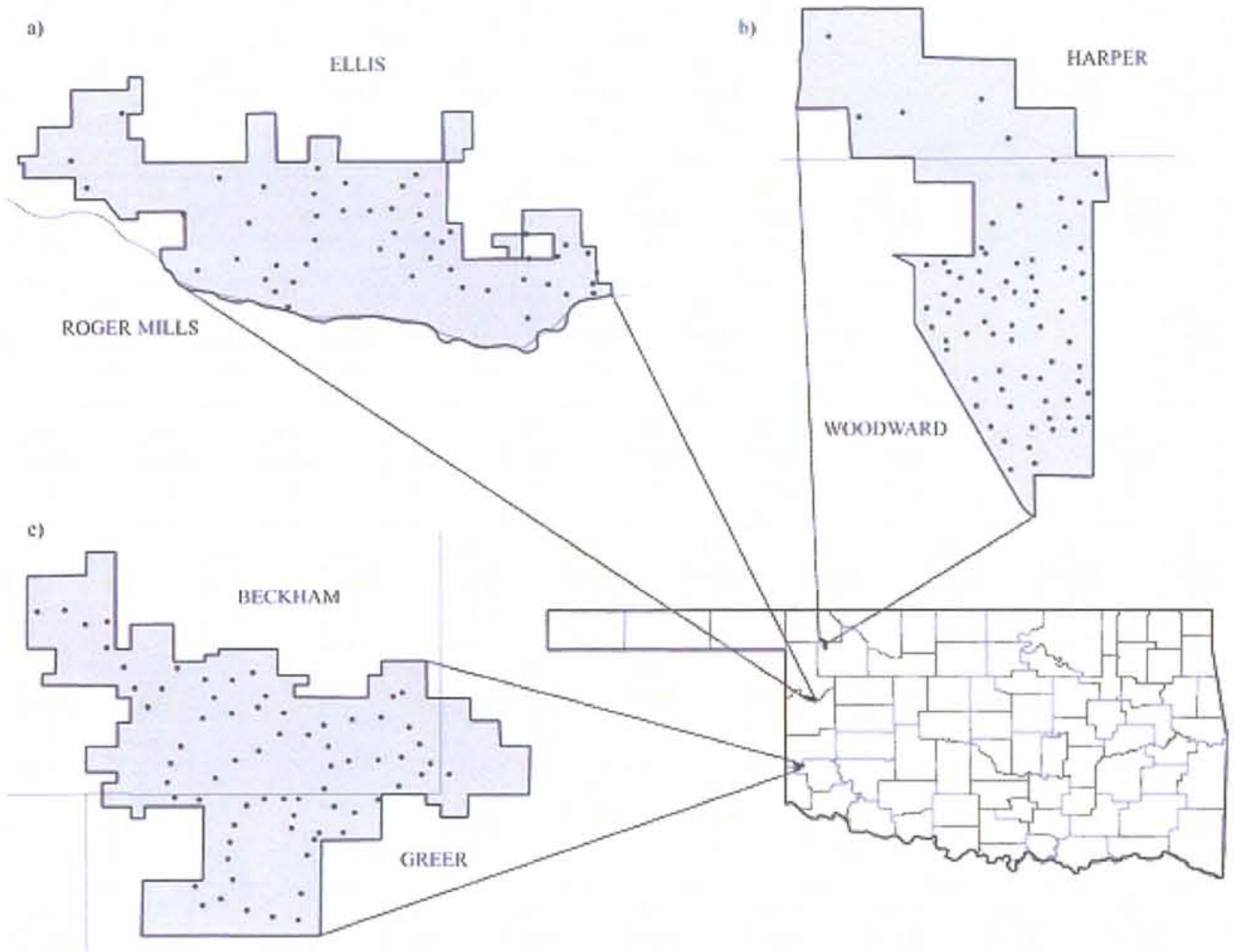

Figure 5— Cooper (a), Packsaddle (b), and Sandy Sanders (c) Wildlife Management Areas (WMAs) of western Oklahoma. Image not to scale.

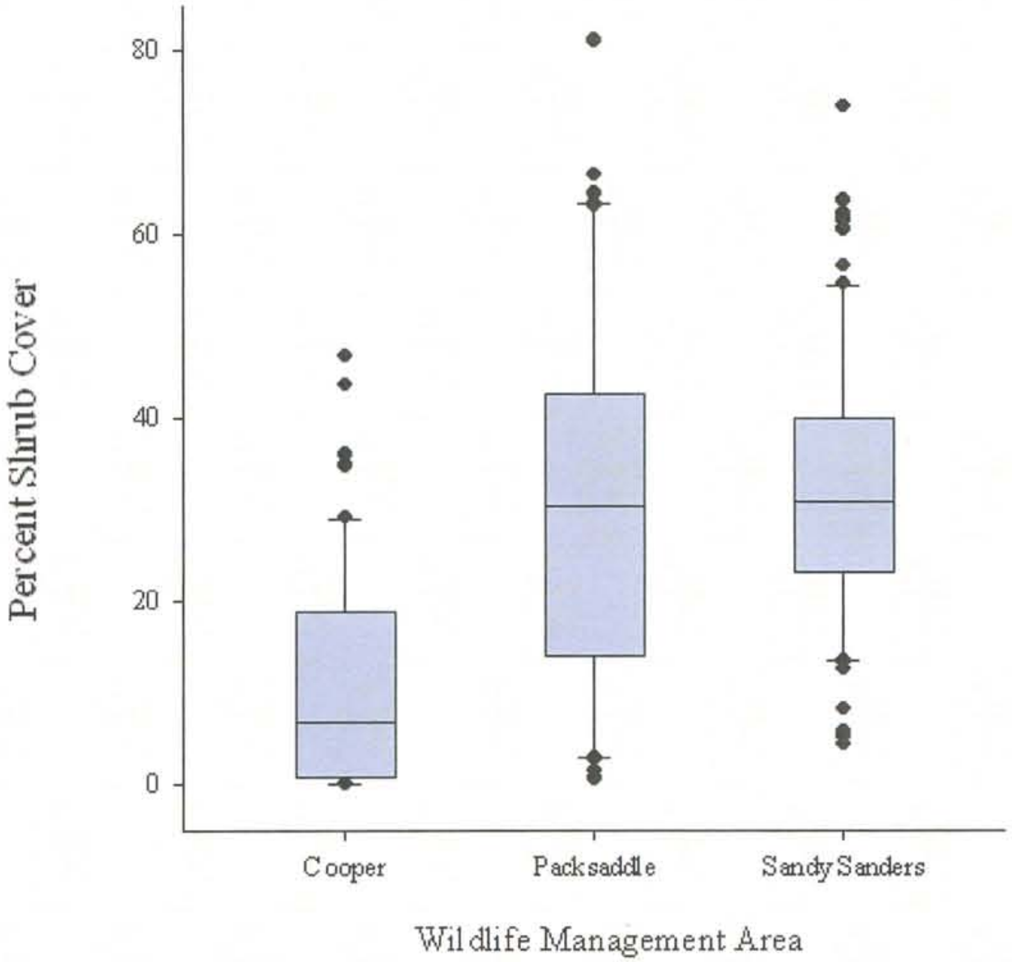

Figure 8—Comparison of shrub percent cover between Cooper, Packsaddle, and Sandy Sanders WMAs showing median, 25th and 75th percentile, 10th and 90th percentile, and individual points above the 90th and below the 10th percential