FINE-SCALE HABITAT ASSOCIATIONS OF SCISSOR-TAILED FLYCATCHERS

(*TYRANNUS FORFICATUS*) IN SOUTH-CENTRAL TEXAS

THESIS

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Master of SCIENCE

by

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Texas State University-San Marcos
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FINE-SCALE HABITAT ASSOCIATIONS OF SCISSOR-TAILED FLYCATCHERS

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

FINE-SCALE HABITAT ASSOCIATIONS OF SCISSOR-TAILED FLYCATCHERS (*TYRANNUS FORFICATUS*) IN SOUTH-CENTRAL TEXAS

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During the last century, North America's grasslands have been severely reduced in area due to land-use change and development. Subsequently, grassland birds have experienced declines, with only 18% of grassland breeding birds increasing or stable in abundance. Birds may respond to habitat structure at different spatial scales and many studies of habitat selection in grassland birds have demonstrated that birds cue into specific structural features of vegetation. Scissor-tailed Flycatchers are insectivorous, neo-tropical migrants that breed in the south-central US. I examined their fine-scale (300 m) habitat associations in south central Texas. I predicted that Scissor-tailed Flycatchers would be positively associated with open habitats such as grasslands, pasture and hay fields since these habitats facilitate their scanning foraging strategy, and negatively associated with forest. I conducted 44 surveys from 9 May 2011 to 15 Dec 2011 by slowly driving rural

roads throughout fifteen counties in central Texas and three along the coast. Four routes were repeated five times each to allow testing of seasonal differences in habitat use. I recorded the GPS locations of all flycatchers encountered on the routes. Using aerial imagery in Google Earth, I measured the distances to the nearest tree and human-built structure for each flycatcher location. Using ArcGIS, I quantified the percent cover of five habitat types within 300 and 170 m of each flycatcher location. Statistical analysis involved comparing the habitat variables of the flycatcher locations to a set of random points along the same routes. There was a significant difference between the flycatcher locations and the random points in the amount of grassland/pasture/hay and forest and urban land. Flycatchers were positively associated with grassland/pasture/hay. Knowledge of the fine-scale habitat associations of Scissor-tailed Flycatchers and other grassland birds could be useful to the successful conservation of these species.

INTRODUCTION

It has been estimated that 80% of North American grasslands have been lost since the late 19th century due to changing land-use practices, especially agriculture and cattle grazing (Samson and Knopf 1994). The extensive prairies of the Great Plains and rangelands of western North America were once subject to grazing by large, roaming herds of bison (*Bison bison*). Fire combined with grazing created a disturbance regime that maintained a mosaic of open short grass prairie and scattered stands of shrubs and small trees; this type of landscape fulfilled the habitat requirements of grassland birds (Brennan and Kuvlesky, 2005).

Conversion of the Great Plains for agriculture has led to the transformation of a once expansive and contiguous ecosystem to a fragmented patchwork of human settlements, fields of cropland, highways and roads, with relatively few fragments of natural grassland remaining (Johnson and Schwartz 1993; Herkert 1994; Murphy 2003; Veech 2006). Modern intensive agriculture, overgrazing, changes in the fire regime, woody plant encroachment and introduction of exotic grasses have left less than 4% of the historical 68 million hectares of tall grass prairie in North America (Herkert 1994; Samson and Knopf 1994; Murphy 2003; Herkert et al. 2003; Wilson et al. 2010). The loss of prairies and grassland was not recognized as a conservation problem until the mid-twentieth century, while the intrinsic value of grasslands was also not recognized until the latter half of the twentieth century (Samson and Knopf 1994). Today, grasslands remain one of the most under-protected ecosystems, even though they compose 40% of the Earth's terrestrial ecosystems (Koper and Nudds 2011). Consequently, grassland bird species have experienced continent-wide declines across North America during the last century. As a group, grassland birds have had the most severe and widespread declines, with only 18% of grassland bird species stable or increasing in abundance (Herkert et al. 2003; Sauer et al. 2003; Ziolkowski et al. 2010). Loss of grassland habitat and the

subsequent decline of grassland birds has been well recognized and a great deal of research has been devoted to elucidating the causes of declines and understanding ecological requirements for grassland birds (Vickery and Herkert 2001; Brennan and Kuvlesky 2005; Ribic et al. 2009). Since the mid-1990's, the number of studies focused on grassland birds has substantially increased (Vickery and Herkert 2001; Ribic et al. 2009). Land bird monitoring programs such as the North American Breeding Bird Survey (BBS) provide abundance data on many grassland species (USGS Patuxent Wildlife Research Center 2003). Breeding Bird Survey data, along with land cover data, Geographic Information Systems (GIS) models and field studies have allowed researchers to better understand patch size sensitivity, area requirements and habitat selection in grassland birds (Brennan and Kulvesky 2005; Winter et al. 2005; Ribic et al. 2009; Fisher and Davis 2010; Koper and Nudds 2011).

Throughout the Great Plains, loss of native grassland habitat may be occurring at different rates in different regions. In Texas, only 10% of the native tall grass prairie and 20% of the short grass prairie remain (Samson and Knopf 1994). Mixed grass prairie has not declined as severely as tall and short grass, but 30% of the historical mixed grass prairie of Texas has been lost (Samson and Knopf 1994). Many grassland passerine species breed in Texas. Furthermore, grasslands also serve as wintering habitat for bird species breeding in grasslands at higher latitudes. Scissor-tailed Flycatchers (*Tyrannus forficatus*) breed in the south-central United States, with the highest densities in Texas and Oklahoma (Regosin 1998). During the period from 1966-2008, analysis of BBS data showed that Scissor-tailed Flycatchers are significantly declining at a rate of 0.6% per year in their entire breeding range, with more severe declines (2.2 % per year) in the most recent five years of the survey, 2003-2008 (Ziolkowski et al. 2010). However, there are areas that support populations that are stable or increasing in abundance throughout Texas, Oklahoma, and Kansas.

Scissor-tailed Flycatchers are sexually-dimorphic, neo-tropical migrants that breed in the south-central United States and winter in southern Florida, and southern Mexico through Costa Rica (Regosin 1998). In both the breeding and wintering habitats, they occupy open areas that provide adequate hunting perches and nest sites including savannahs, prairies, brush patches, agricultural fields and pastures. Additionally, they will

utilize hedgerows, fence vegetation, canopy edges and roadways in prairies and grasslands to nest and forage (Regosin and Pruett-Jones 1995; Nolte and Fulbright 1996; Regosin 1998). Scissor-tailed Flycatchers are sit-and-wait foragers that require hunting perches in their territories. They readily use man-made structures as perching sites, such as utility wires and fences (Fitch 1950; Regosin and Pruett-Jones 1995, Regosin 1998). They usually forage at heights from ground level to 10 m and catch their insect prey by aerial hawking (Regosin 1998).

Birds, such as Scissor-tailed Flycatchers may respond to habitat structure at different spatial scales (landscape, territory, nest site) (Brennan and Schnell 2007) and knowledge of the distribution, characteristics and spatial arrangement of preferred habitats is essential for species conservation (Winter et al. 2005; Brambilla et al. 2009; Ribic et al. 2009). Many studies of habitat selection in grassland birds have demonstrated that birds cue into specific structural features of vegetation, including height and density, at multiple scales (Cody 1981; Cunningham and Johnson 2006; Brambilla et al. 2009). I chose to study the habitat associations of Scissor-tailed Flycatchers at the territory (300 m) scale given that habitat associations at this scale are not well documented for Scissor-tailed Flycatchers. Moreover, this is a small enough scale to practically manipulate in any management effort that would stipulate active alteration (e.g., restoring patches of natural grassland, planting trees for nesting) of the landscape.

The objective of this study was to examine the fine-scale habitat associations of breeding Scissor-tailed Flycatchers in central Texas. Furthermore, Scissor-tailed Flycatchers are not a well-studied avian species so knowledge gathered may be useful for the conservation of this species. If individuals are non-randomly spaced in a landscape and since Scissor-tailed Flycatchers are known to occupy open habitats including grasslands, prairies, pastures, and crop lands, I predict that they will be positively associated with these specific land cover types. Additionally, I predict that land cover types with dense canopy cover lacking hunting perches surrounded by open areas will be negatively associated with Scissor-tailed Flycatchers. Scissor-tailed Flycatchers should avoid these areas since they need open areas and perching structures to support their sit-and-wait predatory foraging strategy.

STUDY AREA

The study area included fifteen counties in south central Texas and three counties, Calhoun, Matagorda and Refugio, along the Texas coast. Most of the survey routes were located in Caldwell, Gonzales, and Guadalupe counties with the remaining routes located in counties surrounding San Marcos (Figure 1).
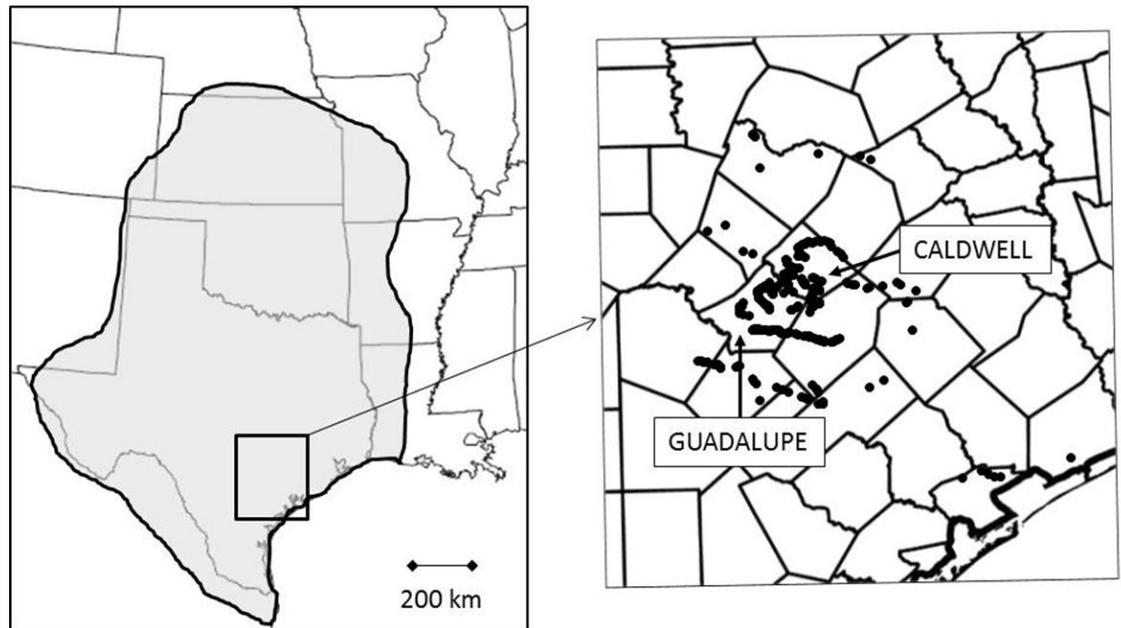

Figure 1. Breeding range (gray shaded area) of Scissor-tailed Flycatchers in south-central USA and northern Mexico. Area surveyed by the routes extended from the coast into central Texas. Map inset shows the locations of the 369 flycatcher observations (with substantial overlap of points). Caldwell and Guadalupe counties had the greatest number of observations.

METHODS

To assess habitat associations at a fine scale (300 m), I conducted 44 surveys between 9 May 2011 and 15 December 2011 along rural roads throughout fifteen counties in central Texas. I used ten Breeding Bird Survey routes including Indianola (83013), Muldoon (83026), Lockhart (83027), Lone Oak (83029), Walburg (83139), Dripping Springs (83140), Leander (83238), Oyster Lake (83306), Yoakum (83314), and Creedmore (83324) (Appendix A), all of these routes were the standard 39.2 km in length typical of BBS routes. The remaining routes were along rural roads with open areas and perching structures, these routes varied in length from 12.8 to 88.3 km, although most of the routes had lengths similar to the BBS routes. In this study, routes were considered only as convenient way to implement the surveying protocol (see below) to get thorough coverage of the study region (Fig. 1). Therefore, few analyses involved testing for differences among routes. Prior to surveying, the routes were "scouted" by viewing ground-level images from Google Earth and sometimes by driving all or part of the route. This was done to ensure that the route was suitable for surveying in the sense of having perching structures (utility wires, barbed wire fences) along most of its length. The entire route did not have to be characterized as open habitat, some routes had wooded areas but at least part of each route included habitats such as grassland, pasture land, and shrub land. Four of the routes (Creedmore, Lockhart, Luling, and Gonzales) were repeat-surveyed on four different occasions about one month apart; this allowed me to test for seasonal differences in habitat associations. I drove each route at low speeds (30 km/h) while an observer and I scanned the roadside perching structures and vegetation for perched birds. This continual-driving protocol of surveying birds has been used previously (Bohall-Wood 1987; Telfer et al. 1989; Smith and Kruse 1992; Gawlik and Bildstein 1993; Esley and Bollinger 2001). I scanned the structures closest to the road and other structures within 100 m of the vehicle. Only birds that were detected within

100 m of the road were counted (most were very near the road). I also recorded birds that were flying. When a Scissor-tailed Flycatcher was detected, I parked the vehicle within 30 m of the bird's location and recorded the time and GPS coordinates. I also noted perch type and height, whether the bird was facing the road or not, and if a large raptor was present. If the flycatcher was flying, all measurements except perch type and height were taken. This information was recorded because *a priori* we thought these variables might affect the distribution and observation of flycatchers. Upon examining the data, there did not appear to be any effects so the variables were not analyzed further. Some observations of flycatchers included multiple individuals (2 – 8) at the same location and sometimes interacting with one another. For statistical analyses these were considered as one observation given that the flycatchers were obviously not acting or being observed independently of one another.

I entered all GPS coordinates of individuals into Google Earth where I measured the distance from the individual to the nearest tree, defined as woody vegetation >1 m in height, and distance to the nearest human-built structure within 300 m. These structures included houses, barns, sheds, and any other man-made building. If a structure was greater than 300 m from the individual, I recorded the distance as 300 m.

I mapped all survey routes on Google Earth, and then I chose random points along each route to compare to the observed locations of flycatchers. The number of random points for each route was equal to the number of observations recorded for the route. Additionally, I measured the distance to the nearest tree and man-made structure for each random point. The random points facilitated the assessment of flycatcher habitat associations by representing the habitat characteristics that were available (to be selected by flycatchers) on the broader landscape. That is, examining species-habitat relationships requires that the general availability of the various habitat types (or specific features) in the study area be quantified and compared to the actual amount of association expressed by the species.

I entered the coordinates for all observations and random points into ArcGIS 10.0 (ESRI, Redlands, CA). Land cover data were obtained from the 2006 version of the National Land Cover Database (NLCD). Within the continental USA, the NLCD classifies land cover in 30 x 30 m pixels to one of 15 main land cover types. I used the

"Tabulate Area" tool in ArcGIS 10.0 to quantify the proportions (or percent cover) of each of these land cover types in 300 m and 170 m radius circular buffers surrounding each flycatcher observation and random point. Land cover data were combined into the following broad categories (numbers in parentheses represent NLCD codes for the land cover types): urban/developed land (21 – 24), forest/shrubland (41, 42, 43, 52), grassland/pasture/hay (71, 81), and cropland (82). The urban/developed cover types represent different intensities of "urbanization"; I combined these given that flycatchers should be negatively associated with each of those four cover types. The three forest cover types were combined with shrubland because all four types have canopy cover >20%, the only difference is in the height of the woody vegetation. In addition, a preliminary analysis revealed that the difference in shrub cover between flycatcher locations and random points was in the same direction and magnitude as the difference for forest; this further justified combining shrub and forest. Grassland and pasture/hay were combined in that all three represent very open habitat with a grass ground cover and very little woody vegetation.

For statistical analysis, the unit of replication was the observation of a single or occasionally multiple flycatchers at a given location (along with the replicates representing random points). The unit is not an individual bird because it is possible that some of the same individuals may have been observed more than once on routes that were surveyed repeatedly. The first step in the statistical analysis involved conducting a one-factor multivariate analysis of variance (MANOVA) to test for a difference between the observed flycatcher locations and the random points in the multivariate variable that simultaneously represented these four habitat variables: percent cover of urban/developed land, forest/shrub land, grassland/pasture/hay, and distance to nearest tree. The latter variable was log-transformed to achieve a normal distribution. The other three variables were normally-distributed (without any transformation) even though all three were percentage data. Cropland was not included in any statistical analyses because of a high percentage (64%) of zero values for the flycatcher locations and the random points. Distance to nearest man-made structure was not included in any statistical analyses because of a high percentage (26%) of values representing "> 300 m". The MANOVA helped control for study-wide Type I error (incorrect rejection of a true null hypothesis)

that can arise when many separate univariate statistical tests are applied to a suite of related variables (Quinn and Keough 2002). Obtaining significance in the MANOVA then warrants univariate significance testing.

Based on results of the MANOVA, I then performed four univariate single-factor analyses of variance (ANOVAs) on each habitat variable separately testing for a difference between flycatcher locations and random points. The ANOVAs allowed me to determine if the flycatchers were "selecting" or associating with cover types and habitat features at a frequency either greater than or less than the general availability of these cover types and habitat features. These analyses were conducted in R (www.r-project.org). To test for a seasonal effect on habitat associations of flycatchers, I performed a two-factor ANOVA with survey occasion (four levels) nested within route (four routes). I applied this ANOVA separately on the same four habitat variables listed above. In these ANOVAs I only used the flycatcher locations (not the random points) given that differences between flycatcher locations and random points had already been tested in the previous ANOVAs. The nested ANOVAs were conducted with the General Linear Model procedure in SYSTAT 12. The mean differences in the four habitat variables between flycatcher locations and random points analyzed at the 170 m buffer distance were about the same as differences at the 300 m buffer distance so no statistical testing was performed on the data within the 170 m buffers.

I also examined habitat associations of Scissor-tailed Flycatchers at a landscape scale to compare to the patterns revealed at the fine scale and also to facilitate comparison to the results obtained by a previous study (Brennan and Schnell 2007). For each of the 10 BBS routes, I used ArcGIS 10.0 to quantify the percent cover of each of the four NLCD cover types (urban/developed, forest/shrub, grassland/pasture/hay, and cropland) within a 0.4 km buffer along both sides of the entire length of the route. Brennan and Schnell (2007) used the same landscape size but a different land cover database. I then performed a separate regression on each cover type and the total number of flycatchers recorded on the route. Because the Creedmore and Lockhart routes were repeated four times, I used the average number of flycatchers recorded over all survey occasions. I also performed a regression for each cover type versus flycatcher abundance

as recorded in the BBS data from 2011. Three (Leander, Lockhart, and Oyster Lake) of the ten routes were not surveyed in 2011 and thus not included in these latter regressions.

RESULTS

I obtained a total of 369 flycatcher observations; 272 (74%) were single individuals and 65 (18%) were two individuals. The remaining observations consisted of three or more flycatchers observed within 50 m of one another. I did not perform any analysis based on number of birds per observation as I could not be certain that the single individuals truly represented solitary individuals. Furthermore, for mated pairs, the mate may have been nearby but not observed making it difficult to confidently distinguish between singletons and doubletons in the data.

The MANOVA revealed a significant difference between the flycatcher locations and the random points in the multivariate habitat variable (Pillai trace statistic = 0.043, $F_{4,733} = 8.15$, $P < 0.00001$). The 300 m buffer zones centered on flycatcher locations had significantly less urban/developed land and forest/shrub land and significantly more grassland/pasture/hay than the buffer zones of random points (Table 1). There was about the same percentage of cropland at the flycatcher locations as at the random points (mean = 12.6, SD = 22.8; mean = 10.3, SD = 19.4, respectively). As previously mentioned, many of the flycatcher locations (234/369) lacked cropland altogether as did many of the random points (236/369). Distance to nearest tree was not significantly different ($P = 0.12$) between flycatcher locations and random points although flycatchers were about 10 m closer to the nearest tree than were random points on average (Table 1). There was little difference between the flycatcher locations and random points in distance to the nearest man-made structure (mean = 180.8 m, SD = 99.5; mean = 176.5 m, SD = 100.8, respectively). There was no seasonal effect on distance to the nearest tree, percent cover of urban/developed land, and percent cover of forest/shrub land in the 300 m buffer zones centered on flycatcher locations. However, there was a seasonal effect on percent cover of grassland/pasture/hay within 300 m of flycatcher locations (Table 2). However, the

seasonal effect was not manifested as any clear directional trend (Fig. 2). Percent cover of grassland/pasture/hay varied significantly among the routes (i.e., the main effect of "route" within the ANOVA, Table 2) with flycatchers associating with this cover type more so on the Lockhart route than the other three routes (Fig. 3). There was also a significant main effect of forest/shrub land cover (Table 2) which mostly arose from flycatcher locations on the Lockhart route having less of this cover type than locations on the other routes (Fig. 3).

At the landscape scale (0.4 km buffers along the entire route), there were not any significant relationships between flycatcher abundance and percent cover for any of the four cover types, regardless of whether abundance estimates were from my surveys or the BBS (Table 3). There were substantial differences among the 10 BBS routes in percent cover of the four main land cover types and differences in flycatcher abundance (Appendix A); nonetheless this variation in the habitat variables did not explain well the variation in flycatcher abundance (Fig. 4).

Table 1. Results of the univariate ANOVAs testing for differences between flycatcher locations and random points for the four habitat variables quantified within the 300 m buffer zones. Values in table are means with standard deviations in parentheses.

Habitat variable	Flycatcher locations	Random points	$F_{1,736}$	P
Distance to nearest tree (m)	39.7 (55.3)	30.5 (52.6)	2.36	0.12
Urban/developed land (% cover)	16.5 (7.7)	18.5 (9.8)	8.83	0.003
Forest/shrub land (% cover)	29.9 (21.7)	36.7 (25.2)	15.25	0.0001
Grassland/pasture/hay (% cover)	38.8 (23.6)	31.2 (22.9)	19.53	<0.00001

Table 2. Results of the nested ANOVAs testing for seasonal differences (survey occasion nested within route) in each of the four habitat variables quantified within the 300 m buffer zones.

Habitat Variable	Effect	F^1	P
Distance to nearest tree (m)	Among routes	1.25	0.29
	Survey occasion within route	0.75	0.70
Urban/developed land (% cover)	Among routes	1.27	0.29
	Survey occasion within route	0.63	0.81
Forest/shrub land (% cover)	Among routes	5.03	0.002
	Survey occasion within route	1.65	0.08
Grassland/pasture/hay (% cover)	Among routes	3.69	0.013
	Survey occasion within route	3.00	0.001

[1] For each of the nested ANOVAs, the degrees of freedom are 3, 12, and 210 respectively for the among route effect, survey occasion nested within route, and error, respectively.

Table 3. Results of the linear regression of Scissor-tailed Flycatcher abundance and land cover type for urban/developed, forest/shrub, grassland/pasture/hay and cropland on ten Breeding Bird Survey routes for the 2011 BBS and the present study.

Habitat Variable	Regression	R^2
Urban/developed land (% cover)		
BBS 2011	y = 2.11x - 6.73	0.18
Present Study	y = 1.43x - 6.78	0.15
Forest/shrub land (% cover)		
BBS 2011	y = 0.05x + 13.2	0.01
Present Study	y = 0.03x + 6.83	0.01
Grassland/pasture/hay (% cover)		
BBS 2011	y = 0.16x + 10.5	0.03
Present Study	y = 0.06x + 6.59	0.01
Cropland (% cover)		
BBS 2011	y =0.18x + 18.56	0.08
Present Study	y = -0.11x + 10.44	0.07
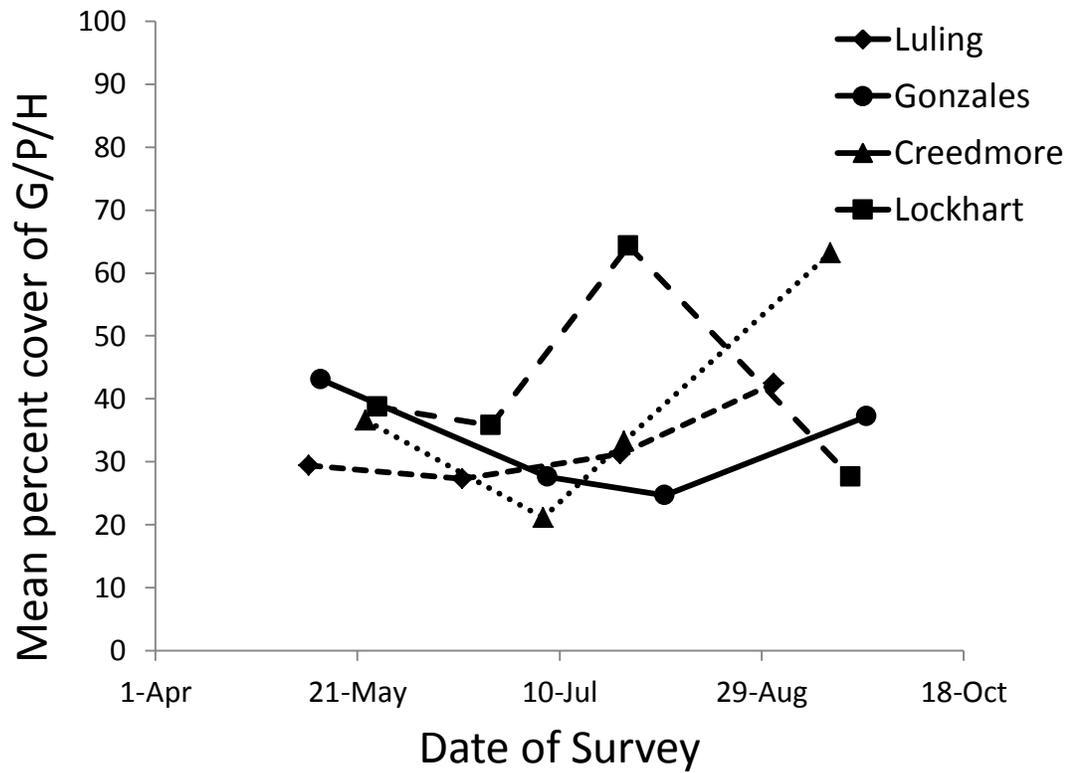
Figure 2. The mean percent cover of grassland/pasture/hay (G/P/H) in the 300 m buffer zones centered on flycatcher locations over the survey period for the four routes that were repeatedly surveyed.
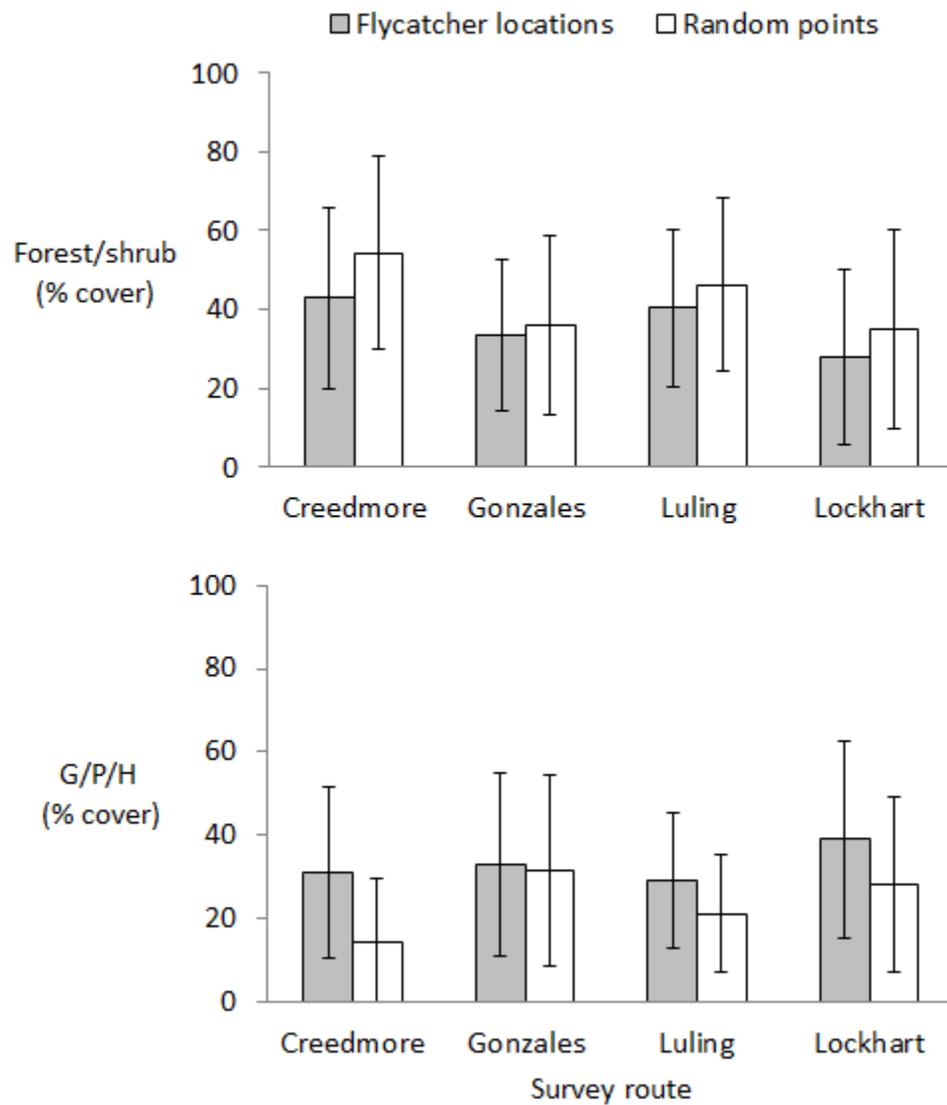
Figure 3. A comparison of the mean percent cover of forest/shrub land and grassland/pasture/hay (G/P/H) in the 300 m buffer zones centered on flycatcher locations and random points for the four routes that were repeatedly surveyed. Error bars represent ± 1 SD.
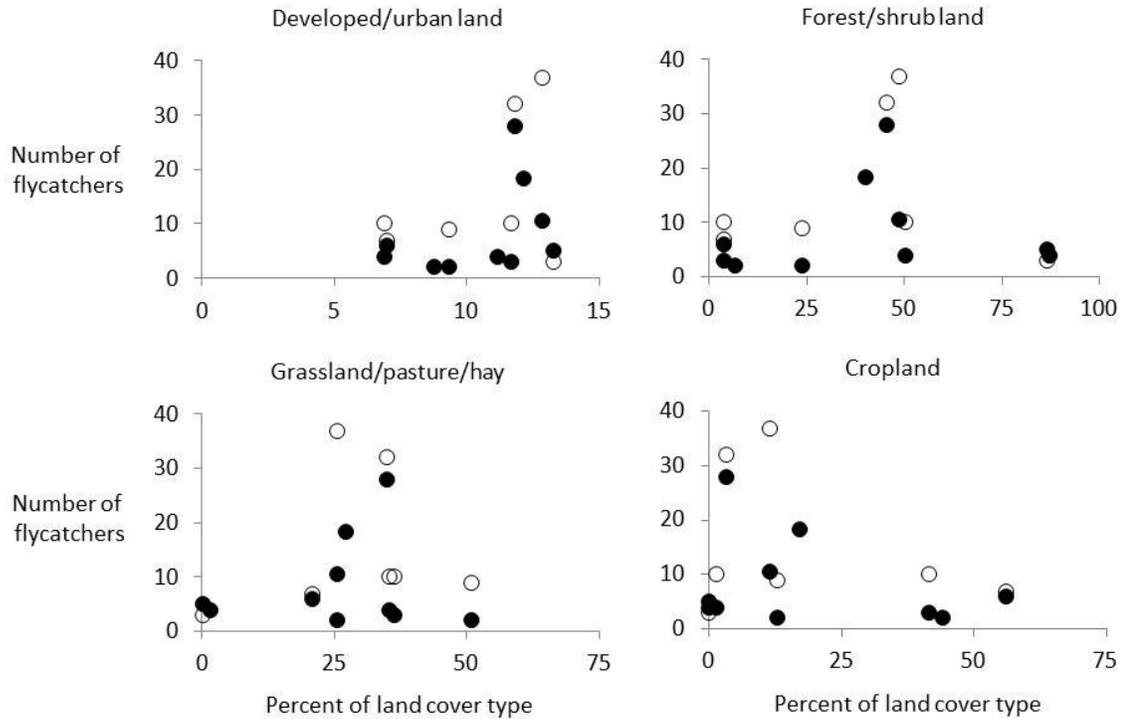
Figure 4. Number of Scissor-tailed Flycatchers recorded on the ten Breeding Bird Survey routes versus the percent cover of each of the four main land cover types in 0.4-km buffers along the length of the route. Solid circles represent flycatchers recorded during my surveys. Open circles represent flycatchers recorded during the 2011 BBS (three of the routes were not surveyed by the BBS in 2011). In my study, two of the BBS routes were each surveyed four times; for these routes, figure shows mean number of birds recorded over the four survey periods.

DISCUSSION

The results supported my prediction that Scissor-tailed Flycatchers will associate more with open habitats (grassland/pasture/hay) than forest or urban. I found that there was significantly more grassland/pasture/hay and significantly less forest/shrub land within the 300 m flycatcher buffer zones compared to random points (Table 1). My study is unique in that it is one of the first to examine the fine-scale habitat associations of Scissor-tailed Flycatchers and I confirmed that they are positively associated with open habitats. Flycatchers tend to select and forage in areas that have more grassland, pasture, and hay fields compared to the background availability of these habitats across the entire landscape (as indicated by land cover composition of the random points). However, on average nearly 30% of the land within flycatcher foraging zones is composed of forest or shrub, indicating that flycatchers do not require foraging areas that are totally devoid of closed-canopy habitats.

The only other published analysis of flycatcher habitat associations was the study of Brennan and Schnell (2007). They used aerial photography and BBS data to study multi-scale habitat associations of seven Tyrannidae species, including Scissor-tailed Flycatchers, in the south-central US. They analyzed bird abundance and landscape variables at 16 spatial scales from a local (0.8 km) to regional (40.2 km) scale along 198 BBS routes. The smallest scale corresponded to a BBS stop and the largest scale represented an entire survey route. Bird abundance was estimated using the average number of birds per stop (or per group of stops for larger spatial scales) per year (1985 – 1994) for each BBS route. Brennan and Schnell (2007) used PCA to reduce a set of 10 landscape variables (measuring landscape composition and spatial configuration) to two composite variables (PC axes I and II). The composition variables were percent cover of open country, closed forest, and intermediate forest which were classified from a previous study (Brennan and Schnell 2005). With the exception of PC axis II representing

the proportion of open and closed (forests) habitat, relationships between Scissor-tailed Flycatcher abundance and landscape characteristics were non-significant and weak at all spatial scales, as indicated by correlation coefficients of $-0.2 < r < 0.2$. However, flycatcher abundance was positively correlated with PC axis II which represented an intermediate mix of open and closed habitats or what Brennan and Schnell (2007) referred to as a "savannah-like" landscape. This association was particularly evident at larger spatial scales (> 8 km) although correlation coefficients were never greater than 0.3.

My study is not directly comparable to Brennan and Schnell (2007) due to differences in the type of land cover data used, different sources or methods for surveying flycatchers, and somewhat different analyses. However some qualitative comparisons can be made. Similar to Brennan and Schnell (2007) I found that Scissor-tailed Flycatchers associate with a savannah-type of landscape but at even smaller spatial scales than those revealed by the former study. In my study, flycatcher locations had on average 38.8 % grassland/pasture/hay and 29.9 % forest/shrub land, a mix that can be described as savannah. My study differs in that I found significant habitat associations at a small spatial scale (300 m), a scale that is relevant to habitat used by a foraging flycatcher, whereas Brennan and Schnell (2007) found few significant habitat associations, especially at smaller scales. Thus, my study is the first to formally document the fine-scale habitat associations of Scissor-tailed Flycatchers.

My study revealed that flycatchers forage in areas that have meaningful amounts of open and closed habitats, instead of predominantly one or the other. Most (246 out of 369) flycatcher buffer zones had more than 10% forest/shrub cover *and* more than 10% grassland/pasture/hay cover. Only 136 random locations were composed in this way. Regosin (1998) describes Scissor-tailed Flycatchers habitat associations as open areas such as prairies and savannahs but he also notes that they will utilize forest edges in the wintering habitat. Forest habitats and edges may provide abundant insect prey. Lastly, some interspersed trees are required in Scissor-tailed Flycatcher habitat since they utilize trees and some shrubs for nesting and perching (Regosin and Pruett-Jones 1995; Regosin 1998).

Distance to the nearest tree was not significantly different between the flycatcher locations and the random locations, although the average distance to the nearest tree for

the flycatcher locations was 10 m greater than the average for the random locations. The average distance to the nearest human-built structure including houses, barns, and sheds was not different between the flycatcher locations and the random locations; however, there were many distance values of greater than 300 m for both the flycatcher locations and the random locations. Scissor-tailed Flycatchers may avoid areas with a high density of man-made structures, but if houses, barns, sheds, or any other human-built dwelling are isolated or dispersed across a landscape, they may not interfere with flycatcher foraging and habitat use. Lastly, the mean amount of cropland did not differ between the flycatcher locations and the random locations, but many of the flycatcher locations and random points (234 and 236 respectively) lacked cropland altogether within the 300 m foraging zones. Scissor-tailed Flycatchers may avoid cropland particularly if the insect prey base is low due to pesticide use. However, in some landscapes, cropland may be useable habitat for Scissor-tailed Flycatchers. Jones et al. (2005) studied bird abundance, diversity, and richness in agricultural lands in Florida and they found that native birds, including insectivores, will use cropland, especially mixed crop fields with hedgerows and woodlots. My study revealed some evidence that cropland might substitute for natural grassland when the latter is uncommon. Of the 26 flycatcher locations that had < 5% grassland/pasture/hay, 14 had > 25% cropland and 8 of those had > 75% cropland. Only 13 and 8 out of 47 random locations were composed in this way. This is only a preliminary inference about cropland; because cropland was an infrequent cover type along most of the survey routes, my study should not be taken as a definitive test of whether Scissor-tailed Flycatchers associate with this cover type.

There was a significant within-route effect of season on habitat associations for the four routes that were repeatedly surveyed. The mean percent cover of grassland/pasture/hay within 300 m of flycatcher locations differed throughout the summer for the repeated routes, most notably the Creedmore and Lockhart routes (Fig. 2), but there was no consistent trend in association with grassland/pasture/hay in relation to the breeding season (first part of summer compared to latter part).

Issues related to Scissor-tailed Flycatcher Conservation

Few studies have been conducted on this species particularly with regard to examining habitat associations. However, there are general descriptions of the habitat and ecology of Scissor-tailed Flycatchers that date back over 100 years. Bailey (1902) described their behavior and distribution on the mesquite prairies of south Texas. Fitch (1950) reviewed the distribution of Scissor-tailed Flycatchers and describes them as associated with prairies and open lands. He mentions the prairie habitat of Scissor-tailed Flycatchers in Brazos County, TX "as the preferred habitat" (Fitch 1950). He also examined nest site selection and reported that they prefer mesquite trees, thus providing early evidence that Scissor-tailed Flycatchers prefer open habitat with interspersed trees and shrubs (Fitch 1950). Warner (1966) describes their breeding range in Oklahoma as encompassing most of the state except for the oak-hickory forests of the eastern edge of the state. Therefore, the Scissor-tailed Flycatcher has long been known as a species that exists in open prairie and grassland habitat, even though few studies have quantitatively documented this habitat association, particularly at relatively small spatial scales typical of the habitat that an individual bird actually uses on a daily basis.

Regosin and Pruett-Jones (1995) conducted studies on reproductive success of Scissor-tailed Flycatchers in the mesquite mixed-grass prairie of southwestern Oklahoma. Furthermore, Nolte and Fulbright (1996) examined nest site selection in this species in the mesquite and little bluestem mixed grass prairie of Welder Wildlife Refuge in south Texas. They found nesting shrubs and trees were selected non-randomly based on the available trees and shrubs with 90% Scissor-tailed Flycatchers nests located in mesquite, although only 20% of the available shrubs were mesquite (Nolte and Fulbright 1996). They also found that vegetative characters, including horizontal cover, vertical cover, and distance to nearest shrub, of the nest tree site were different between flycatcher nests and random points. Scissor-tailed Flycatcher nests had more vertical cover, greater distance to nearest shrub, and more open land surrounding the nest tree (Nolte and Fulbright 1996). These studies provide information on the characteristics of the habitats (prairies) that are known to hold breeding populations of Scissor-tailed Flycatchers. Lastly, general descriptions of the occurrence of the species in prairies and open country including pastures, hayfields, and grasslands can be found in avian field guides and Regosin (1998).

Since the continent-wide decline of grassland birds is thought to have resulted from habitat loss and degradation, the first step to grassland bird conservation is identifying the habitat preferences and locations of suitable habitat for the species of interest (Vickery and Herkert 2001; Brennan and Kuvlesky 2005; Fisher and Davis 2010). Scissor-tailed Flycatchers have experienced declines throughout their range, but there are areas that hold stable and/or increasing populations (Ziolowski et al. 2010). Information about the preferred habitats of Scissor-tailed Flycatchers and habitats holding the greatest densities (located in Texas and Oklahoma) can help guide conservation plans and population monitoring for this species (Regosin 1998), including possibly grassland and hayfield management conducive to flycatchers.

The management of rangeland (natural grasslands) and hayfields has changed in recent decades with more frequent harvests and earlier harvesting dates; this is believed to be one cause of grassland bird declines (Samson and Knopf 1994; Troy et al. 2005; Perlut et al. 2006). A few studies of grassland birds have examined the management and date of haying harvest in grassland bird breeding habitat. Perlut et al. (2006) studied the effects of four different hay harvest dates on the nest success of two grassland bird species in New York. They found that early harvests led to high nest failures and the number of fledglings increased the later the date of hay harvest (Perlut et al. 2006). Additionally, mowing can result in territory abandonment and higher mortality for roosting adults (Frawley and Best 1991; Rodenhouse et al. 1995). If harvest and mowing greatly affect vegetation structure and prey availability in flycatcher foraging zones, then there may be an effect on habitat use with potentially deleterious effects for the population. Additionally, livestock grazing may positively or negatively affect grassland breeding birds, depending on the required vegetation structure and life history of the species. Some species are positively affected by grazing, such as Horned Larks and Dickcissels, while others are negatively affected by grazing, including Savannah, Baird's, and Henslow's sparrows (Rodenhouse et al. 1995). Additionally, the response of other grassland bird species (Grasshopper Sparrow and Bobolink) to grazing depends on the type of grassland inhabited (short, mixed, or tallgrass) (Rodenhouse et al. 1995). Since I found that Scissor-tailed Flycatchers are positively associated with pasture and hay as well as grasslands, perhaps their response to grazing is positive, but further examination

of the grazing regimes of the inhabited pastures are under may lead to a better understanding of Scissor-tailed Flycatcher response to specific grazing regimes (i.e. rotational low and high-density grazing and uniform grazing). This information could guide land managers to the grazing regime that most benefits Scissor-tailed Flycatchers and other grassland breeding birds.

Although some harvest and grazing practices can have harmful effects on populations of grassland birds, pasture, hay, and croplands can provide habitat in the form of fields, hedgerows, and edges for grassland birds, including neo-tropical migrants (Rodenhouse et al. 1995). As previously mentioned, Jones et al. (2005) found that insectivorous birds will readily use organic and conventional croplands with mixed crops and croplands with a mosaic of adjacent habitats including fencerows, hedgerows, and woodlots. Grassland birds have been documented using agricultural lands, especially fields enrolled in the Conservation Reserve Program (Frawley and Best 1991; Rodenhouse et al. 1995; Troy et al. 2005; Rahmig et al. 2008; Herkert 2009; Cerzo et al. 2011; Wilson and Brittingham 2012). In addition, wooded edges near pastures or croplands may provide a greater abundance of insect prey and perching sites, which may be beneficial to Scissor-tailed Flycatchers and other insectivorous grassland birds (Peng et al. 1993, Rodenhouse et al. 1994).

In the present study, Scissor-tailed Flycatchers continued to use grassland/pasture/hay throughout the summer (Fig. 2). Given this pattern, management practices that enhance Scissor-tailed Flycatcher habitat will need to be practiced throughout the breeding season, or timed so that they have the most positive effect on Scissor-tailed Flycatchers breeding and foraging in those areas. A closer examination of Scissor-tailed Flycatcher response to different grazing regimes is needed to fully understand the effects of grazing on this species.

Studying habitat selection allows us to link habitat preferences to conservation of a certain species or multiple species of interest (Indermaur and Schmidt 2011). An important step in grassland bird conservation is to identify areas of remaining habitat suitable for management and conservation (Vickery and Herkert 2001; Brennan and Kulvesky 2005). Fisher and Davis (2010) reviewed the available literature on habitat selection in grassland birds to summarize methods use for quantifying habitat use and to

identify patterns of vegetation associations of grassland birds. Their goal was to guide future studies of grassland bird habitat by identifying a reduced set of relevant vegetation characteristics for researchers to consider when examining habitat selection of grassland birds, as well as to highlight the need for consistent definitions of terms for analyses of habitat selection of grassland birds. They point out the importance of consistency in grassland bird habitat studies to better serve conservation science and managers (Fisher and Davis 2010).

An examination of the habitat associations at larger scales could be conducted to determine if the positive relationship between the amount of open habitats and Scissor-tailed Flycatchers is also significant at a landscape level using similar methods collecting presence/absence data instead of using abundance data from the BBS as Brennan and Schnell (2007) did. My study is one of the few to examine the habitat associations of Scissor-tailed Flycatchers at a fine-scale relevant to a foraging individual. I found a significant response at this scale, in contrast to Brennan and Schnell (2007) who found only weak habitat associations at small scales. Effective conservation of Scissor-tailed Flycatchers will require more knowledge of habitat selection including nest-site selection, grazing regime response and habitat associations on a landscape scale (≥ 1 km) integrated with this study on fine-scale habitat associations. Scissor-tailed Flycatchers associate with landscapes that have sufficient open areas such as grasslands, pastures, and hayfields *and* some shrubland or forest. Previous descriptions and studies of habitat use emphasize the importance of open areas to breeding Scissor-tailed Flycatchers, but none considered shrubland and forest types as suitable flycatcher habitat. Although they may utilize open habitats to forage, the presence of closed habitats in the landscape seems to be important to Scissor-tailed Flycatchers. This insight may be important for successful conservation of this species.

APPENDIX A

Characteristics of the ten Breeding Bird Survey routes that were surveyed in the present study. All routes were the same length (39.2 km) and were surveyed once between May and September 2011, except for Creedmore and Lockhart which were surveyed four times each. Information presented below includes route name, number, latitude and longitude coordinates of the two end points, total number of flycatcher observations, total number of birds, total number of birds recorded by BBS in 2011, percent cover of urban/developed land, forest/shrub, grassland/pasture/hay, and cropland within 0.4-km buffers along the route. Symbol "*" indicates that the value is a mean over four survey periods. "N/A" indicates data not available for the three BBS routes that were not surveyed by the BBS in 2011.

INDIANOLA (83013) – 28.554/96.544, 28.455/96.887, 5, 5, 6, 7.00%, 3.68%, 20.93%, 56.15%

MULDOON (83026) – 29.816/97.070, 29.483/974, 2, 2, 9, 9.34%, 23.85%, 50.82%, 12.77%

LOCKHART (83027) – 29.992/97.625, 29.781/97.836, 11*, 18.25*, 10.75, N/A, 12.14%, 39.98%, 27.23%, 17.09%

LONE OAK (83029) – 29.275/98.255, 29.354/98.256, 21, 28, 32, 11.81%, 45.47%, 34.99%, 3.23%

WALBURG (83139) – 30.640/97.289, 30.675/97.585, 3, 5, 10, 11.68%, 3.86%, 36.35%, 41.58

DRIPPING SPRINGS (83140) – 30.250/98.058, 30.090/98.194, 1, 5, 3, 13.31%, 86.53%, 0.16%, 0.00%

LEANDER (83238) – 30.8217/97.932, 30.584/97.835, 4, 5, N/A, 11.16%, 87.14%, 1.65%, 0.00%

OYSTER LAKE (83306) –28.614/96.211, 28.868/96.209, 5, 5, N/A, 8.79%, 6.69%, 25.52%, 44.17%

YOAKUM (83314) – 29.274/97.143, 29.278/97.402, 2, 4, 10, 6.90%, 50.15%, 35.35%, 1.36%

CREEDMORE (83324) – 29.994/97.429, 30.055/97.689, 6.25*, 10.5*, 37, 8.79%, 6.69%, 25.52%, 44.17%

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