Patterns of Carnivore Distribution and Occurrence in the Oklahoma Panhandle

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Carnivore distributions in the Oklahoma panhandle were determined through the use of baited, stainless steel tracking plates and verified with infra-red triggered cameras. Tracking plates were operated for two years covering four seasons (October 1995-February 1997). Six species of carnivores were detected in sufficient numbers to permit analyses during tracking efforts in the Oklahoma panhandle (Swift fox (*Vulpes velox*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), spotted skunk (*Spilogale putorius*), striped skunk (*Mephitis mephitis*), and badger (*Taxidea taxus*)). In general, Oklahoma panhandle carnivores were not distributed evenly across panhandle counties or habitats. Canid distributions were skewed toward Cimarron County, however individual canid species exhibited separate habitat preferences within counties. Mustelids and mephitids were distributed evenly across the broader panhandle landscape, but demonstrated clear habitat preferences when detection data were combined at the Family level. Carnivores were also sensitive to the presence of other carnivores within panhandle habitats. This response was most pronounced between the canid species.

Introduction

In western Oklahoma, few comprehensive investigations of carnivores have been undertaken (Glass 1956; Kilgore 1969). Most of the information on carnivores in the state has occurred in conjunction with and ancillary to projects focused on other vertebrates (Shackford et al. 1989; Shackford and Tyler 1991; Peoples and DeMaso 1996). This study had three objectives. The first was to survey carnivores of the Oklahoma panhandle. Historically, the Oklahoma panhandle has supported a diverse carnivore community. Carnivores from the region include 17 species in five families (Caire et al. 1989; Table 1). Four species, gray fox (*Urocyon cinereoargenteus*), western spotted skunk (*Spilogale gracilis*), hog-nosed skunk (*Conepatus mesoleucus*) and ringtail (*Bassariscus astutus*), are thought to be restricted to a small mesa region in the northwestern corner of the Oklahoma panhandle (Caire et al. 1989). The badger (*Taxidea taxus*), black-footed ferret (*Mustela nigripes*), swift fox (*Vulpes velox*) and coyote (*Canis latrans*) are thought to be associated with prairie dog (*Cynomys ludovicianus*) towns (Shackford and Tyler 1991). These and the remaining panhandle carnivores (Table 1) are also more widely distributed and may be found throughout the panhandle.

The second objective was to determine the distributions of carnivores in the Oklahoma panhandle with respect to major habitats. Presently, there exist four broadly classified types of habitat in the Oklahoma panhandle. Mesa habitat extends into New Mexico and Colorado, where it is found more extensively. Mesa habitat is dominated by sand sagebrush (*Artemisia filifolia*), juniper (*Juniperus*

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Table 1 – Carnivores of the Oklahoma panhandle (from Shackford and Tyler 1991; Caire et al. 1989). * Indicates species extirpated from the Oklahoma panhandle.

Scientific Name	Common Name
Family Mustelidae	
Taxidea taxus	Badger
Mustela nigripes	Black-footed ferret
Mustela frenata	Long-tailed weasel
Family Mephitidae	
Mephitis mephitis	Striped skunk
Spilogale putorius	Eastern spotted skunk
Spilogale gracilis	Western spotted skunk
Conepatus mesoleucus	Hog-nosed skunk
Family Canidae	
Vulpes velox	Swift fox
Vulpes vulpes	Red fox
Urocyon cinereoargenteus	Gray fox
Canis latrans	Coyote
*Canis lupus**	Wolf
Family Felidae	
Lynx rufus	Bobcat
Felis concolor	Cougar
Family Procyonidae	
Procyon lotor	Raccoon
Bassariscus astutus	Ringtail
Family Ursidae	
Ursus americanus	Black bear

scopulorum) and two-needle pinyon (*Pinus edulis*). Large, conspicuous riparian areas are also evident in the panhandle. Several riparian areas run predominantly west-east through the Oklahoma panhandle and are dominated by large eastern cottonwoods (*Populus deltoides*), shrubs and taller grasses. Grassland/range areas are dominated by a variety of native and introduced grass species. Grassland/range areas all experience some degree of grazing by domestic cattle. The final major habitat type, agriculture, has come to prevail across several parts of the panhandle. The dominant crops in the panhandle are wheat, winter wheat, corn, and milo. As these agricultural areas can be extensive and uniform, they cannot be ignored as potential habitat for Oklahoma carnivores.

The third objective was to examine whether carnivore distributions and habitat affinities are influenced by the distributions or presence of other carnivore species. Specifically, do different carnivore species (particularly closely-related carnivore species) in the Oklahoma panhandle occur together regionally or in specific habitats more or less than would be expected by chance? We examined not only the effects of large scale factors such as habitat on carnivore distributions, but also how local processes influence where carnivores occur. This approach provides for a better, more comprehensive understanding of carnivore interactions and distributions in the Oklahoma panhandle.

A previous publication (Shaughnessy 2003) on panhandle carnivores compared detection method efficacy and examined swift fox distributions alone, using tracking plate detection frequencies instead of total number of detections. The use of tracking plates was determined to be more effective at detecting carnivores than dirt tracking, spotlighting or the use of infrared cameras (Shaughnessy 2003). Swift fox distributions in the panhandle, as determined by detection frequencies, were examined independently of other carnivore detection data (Shaughnessy 2003). No analyses examining the panhandle carnivore community distributions were presented (Shaughnessy 2003). Detection frequencies were also used, instead of total number of detections, to examine any interactions between swift foxes and coyotes (Shaughnessy 2003). This current work expands the analyses of swift fox distributions by including swift fox total detection data with that of the other panhandle carnivores, presenting power analyses to examine the strength of the applied statistics and interpreting results in conjunction with data from the broader mesocarnivore community.

Study Area

Research on carnivores was conducted in the Oklahoma panhandle, a strip of land about 267 km long (east-west) and 55 km wide (north-south) adjacent to the northwestern-most part of the body of the state. The panhandle region is comprised of three counties, each of about equal size. The counties (from east to west) are Beaver (470,172 hectares), Texas (527,855 hectares), and Cimarron County (475,506 hectares).

Historically, the panhandle consisted primarily of shortgrass prairie (Duck and Fletcher 1943) and was dominated by blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*) and prairie three-awn (*Aristida oligantha*). Prairie dog towns also covered much of the panhandle, occurring in all habitat types (Shackford and Tyler 1991; Shackford et al. 1989). Presently, the landscape has been altered. While the historical habitat types persist, their quality and quantity has changed. The grassland, mesa and riparian areas now are grazed by domestic cattle. The severity of this grazing varies among habitats and locations. Prairie dog towns have been reduced in number and size due to the combined effects of periodic plague (*Yersinia pestis*) episodes and concentrated eradication efforts. Agricultural areas, present since at least 1893, cover a substantial area. These extensive monocultures have had a profound impact on the composition of the vegetation in the panhandle.

Methods

The distribution of carnivores was determined primarily through the use of baited tracking plates at pre-established tracking stations and supplemented with infrared photography. Tracking plates were made of sheets of stainless 26-gauge steel about one square meter in size and sprayed with a mixture of carpenter's chalk and isopropyl alcohol (G.M. Fellers, Biological Resources Division, USGS, pers. comm.). These materials were selected over traditional sand tracking techniques for two reasons. First, tracks in the chalk tended to persist longer and were clearer than tracks in sand under the typical high wind conditions of the panhandle. Second, plate and chalk stations were easier to establish and less expensive to operate repetitively than sand stations. Each plate had a one-inch (2.5 cm) hole drilled through its center, allowing it to be placed directly over a stake that permanently marked the tracking station (Shaughnessy 2003). Canned mackerel and beef scraps were then placed in the center of each plate or on the stake to serve as bait (Shaughnessy 2003). The plates were checked for tracks and recovered after three nights (Egoscue 1956; Hatcher 1978; Pocatello Supply Depot progress report 1981; Orloff et al. 1986; Paveglio and Clifton 1988).

Ninety permanent tracking stations were established throughout the panhandle according to a stratified design (Shaughnessy 2003). Tracking stations were distributed first according to county size. Stations were then distributed across habitats based upon estimates of the total area habitats covered in the panhandle. The minimum number of permanent tracking stations established in any habitat was 12 in each of the mesa and riparian habitats. The most stations (43) were placed in range/grassland habitat (Shaughnessy 2003). Four carnivore tracking surveys, covering each season of the year, were completed from January 1995 to February 1997.

Infrared-triggered cameras were also used in order to detect and verify carnivore presence. The camera units were set at tracking plate stations so that the infrared trigger and the camera were aimed at the center of the station. Ten cameras operated during each sampling trip at tracking stations. Cameras were placed at stations based upon the prior tracking history of the station and a qualitative judgment of the potential of the habitat to produce carnivore detections. Cameras were also placed at stations that appeared to be in areas of high carnivore densities or high quality carnivore habitat that had not tracked carnivores to that point. While cameras were useful for a few novel detections of carnivores, the cameras functioned primarily for verifying carnivore tracks at tracking plates (Shaughnessy 2003).

Statistical Methods

Carnivore landscape distributions were analyzed through chi-square analyses (Zar 2010). Data were compiled by detections within panhandle counties. The panhandle counties are conveniently oriented in-line from west to east and are of roughly equal in size. Chi-square was used to analyze these data according to their distributions across counties to determine if differences existed in gross distributions of carnivores across the panhandle. These data were analyzed for all carnivores, groups of carnivores based on taxonomic relationships and for individual carnivore species.

A second series of tests analyzed carnivores in habitats. Data were compiled for the four major pre-defined habitat types. Chi-square analyses were used to determine if carnivore distributions and occurrences were random across these habitats. These analyses were performed for all carnivores, groups of carnivores, and all individual carnivore species.

Finally, a third chi-square analysis was performed. A chi-square contingency table was used to analyze interspecific associations between carnivores within habitats. In particular, associations between taxonomically related carnivores were examined within Oklahoma panhandle habitats. This test was used to determine if carnivores within certain taxonomic groups were interacting with each other across the broader panhandle landscape. These interactions, if present, could then be used to further explain overall patterns of carnivore occurrence within habitats. This analysis was completed for all carnivores, canids and mustelids/mephitids.

Sample sizes during this project were not large. As a result, power analyses were conducted and reported on all non-significant chi-square results in order to determine the likelihood of the commission of Type II errors. Power values were computed using Cohen (1977) as a reference and evaluated as to their strength according to recent literature (Greenwood 1993; Taylor and Gerrodette 1993; Thompson and Neill 1993; Thomas and Juanes 1996; Zielinski and Stauffer 1996; Marshal and Boutin 1999). These values were used in the further interpretations of non-significant statistical results.

Results

Six carnivores (no distinction was made between western and eastern spotted skunks) were detected in sufficient numbers to permit statistical analysis. These carnivores represent four families (Canidae, Felidae, Mephitidae and Mustelidae) of six possible families reported present in the Oklahoma panhandle. Because of their close taxonomic affiliation, similar sizes, and habitats, data for mustelids and mephitids are combined.

Sampling Effort

Tracking plates were operated for 850 plate nights in the Oklahoma panhandle (Table 2). A plate night is defined as one tracking plate, baited and coated with chalk, set out for one night. Cimarron County recorded the most plate nights, while Beaver County accounted for the least number of plate nights (Table 2). Tracking plate nights were established in range/grassland areas most. The fewest tracking plates were located in mesa and riparian areas (Table 2). These numbers reflect the proportions that habitats and counties occupy within the total area of the Oklahoma panhandle.

Analyses

The results of chi-square analysis of carnivore occurrences across counties is highly statistically significant (X^2 = 26.90, df = 2, p ≤ 0.001; Figure 1). Chi-square analysis of carnivore distributions among habitats also reveals significant differences in the occurrence of carnivores in the habitats (X^2 = 12.11, df = 3, p ≤ 0.01; Figure 2).

Two canid species were detected with sufficient regularity to permit analyses. Swift fox and coyote were detected in all habitats and during all sampling periods. Analyses of swift fox in the Oklahoma panhandle are dealt with more extensively in Shaughnessy (2003), yet in all cases, swift fox distributions are significantly different from expected frequencies or occurrences. Chi-square analysis of swift fox distributions across counties is highly significant (X^2 = 27.04, df = 2, p ≤ 0.001; Figure 3). Swift fox distributions among habitats are similarly uneven. Chi-square analysis shows significant differences in the numbers of detections of swift foxes between habitats (X^2 = 12.02, df = 3, p ≤ 0.01; Figure 4).

The analyses for coyotes produced similar results. Coyotes are not evenly distributed between the three counties of the Oklahoma panhandle (X^2 = 10.49, df = 2, p ≤ 0.01; Figure 5). Additionally, coyotes are not distributed evenly among the broadly defined habitats. Chi-square analysis revealed significant differences in coyote detections across the habitats (X^2 = 18.94, df = 3, p ≤ 0.001; Figure 6).

In general, the results are the same when the data for the two canid species are combined. The chi-square analysis indicates that canids are not evenly distributed across the three counties (X^2 = 24.35, df = 2, p ≤ 0.001). Canids are not evenly distributed among the major habitats of the panhandle either (X^2 = 16.28, df = 3, p ≤ 0.001).

One mustelid and two mephitid species were detected during the course of this study. The spotted skunk, striped skunk, and badger were detected with tracking plates and incidentally. The spotted skunk was detected most frequently. Chi-square analysis examining spotted skunk occurrence among counties reveals no significant differences in spotted skunk occurrences among the counties (X^2 = 4.21, df = 2, p > 0.05). Power for this test is high ($U_{0.05}$ = 2, w = 0.5962, Power = 0.75). Similarly, chi-square analysis shows no significant differences in spotted skunk detections between major habitats (X^2 = 2.53, df = 3, p > 0.05). Statistical power for this test is high as well ($U_{0.05}$ = 3, w = 0.5821, Power = 0.70).

Chi-square analysis of badger detections between panhandle counties is also not significant. Badgers exhibit no significant differences between the counties (X^2 = 1.71, df = 2, p > 0.05). Statistical power for this test is comparatively high ($U_{0.05}$ = 2, w = 0.6429, Power = 0.71). Badgers also are not detected in any habitat more often than expected (X^2 = 3.54, df = 3, p > 0.05). Power for this test is marginal ($U_{0.05}$ = 3, w = 0.5379, Power = 0.54).

The final mephitid species examined was the striped skunk. Results are not significant for striped skunk occurrences between counties (X^2 = .017, df = 2, p > 0.05). Statistical power for this test is very low, however ($U_{0.05}$ = 2, w = 0.1414, Power = 0.02). Chi-square analysis does reveal that striped skunks are not detected evenly among habitats (X^2 = 9.93, df = 3, p ≤ 0.025).

The mustelid and mephitid data were grouped and analyzed to determine if any differences are manifested at higher mesocarnivore levels. The chi-square analysis of mustelid/mephitid occurrences across counties shows that these small mesocarnivores do occur evenly between counties ($X^2 = 3.68$, df = 2, p > 0.05). Power for this test is also low ($U_{0.05} = 2$, w = 0.3209, Power = 0.43). The chi-square analysis of mustelid/mephitid occurrences between habitats reveals that collectively the three species do not occur evenly in all habitats ($X^2 = 7.8225$, df = 3, p ≤ 0.05; Figure 7).

One felid was detected during this study, the bobcat. Chi-square analysis indicates that bobcats occur evenly between the counties and therefore across the panhandle in general ($X^2 = 3.29$, df = 2, p > 0.05). Power for this test is relatively high ($U_{0.05} = 2$, w = 0.6165, Power = 0.61). Analysis of bobcat occurrence among habitats is also insignificant ($X^2 = 6.91$, df = 3, p > 0.05). Statistical power for this test is low ($U_{0.05} = 3$, w = 0.4472, Power = 0.32).

Our final analyses attempt to examine potential interspecific associations occurring between carnivores in the panhandle. These results may be used to understand patterns in occurrence and detections among panhandle habitats. Chi-square contingency table analysis reveals that a significant interaction exists between the two canid species ($X^2 = 13.62$, df = 3, p ≤ 0.005; Figure 8). For mustelids and mephitids, chi-square contingency table analysis reveals that no significant interactions occur between species ($X^2 = 8.60$, df = 6, p > 0.05). Statistical power for this test is marginal ($U_{0.05} = 5$, w = 0.4351, Power = 0.54). Intraorder level interactions are present among all canids and mustelids as well, at significant levels throughout the panhandle ($X^2 = 34.06$, df = 12, p ≤ 0.001).

Discussion

This current work demonstrates that carnivores are not distributed evenly across the Oklahoma panhandle in counties or in habitats. Carnivores are detected most often in Cimarron County and less often than expected in either Texas or Beaver counties. These data imply a gradual decline in carnivore occurrence from west to east in the Oklahoma panhandle.

Carnivores also exhibit non-random trends in occurrence within specific habitats. Carnivores are detected more often than expected in the mesa and agricultural areas. Carnivores are detected as often as expected in riparian areas, but are underrepresented in grassland/range areas. These patterns likely reflect occurrence trends in individual carnivore species.

Canids

Occurrence and distribution patterns in

Table 2 - Sampling effort in counties and habitats of the Oklahoma panhandle expressed as functional plate nights, January 1995 - February 1996.

	Cimarron County	Texas County	Beaver County	Total
Agriculture	13	108	80	201
Mesa	136	0	0	136
Range	104	132	140	376
Riparian	43	51	43	137
Total	296	291	263	850

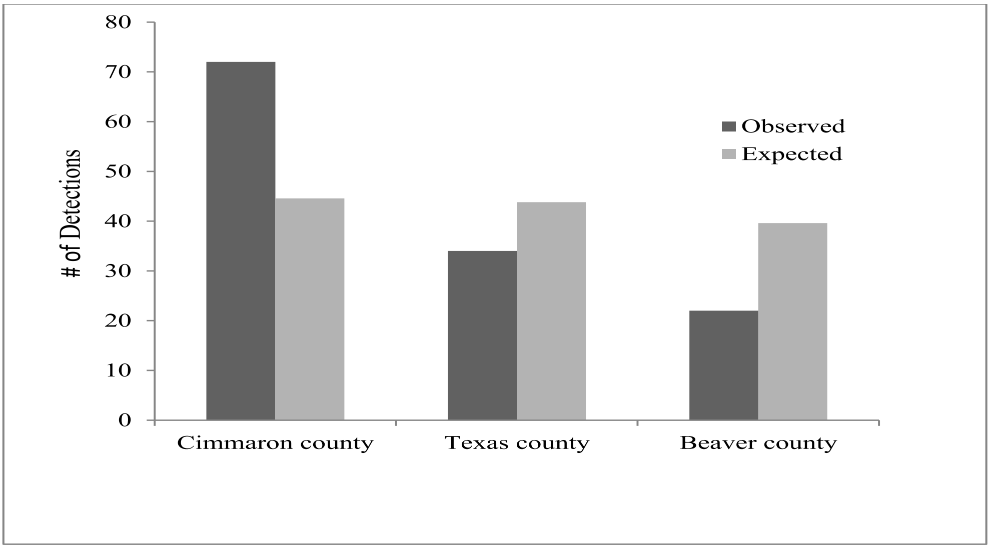

Figure 1 - All carnivore detections across the Oklahoma panhandle counties (p < 0.001).

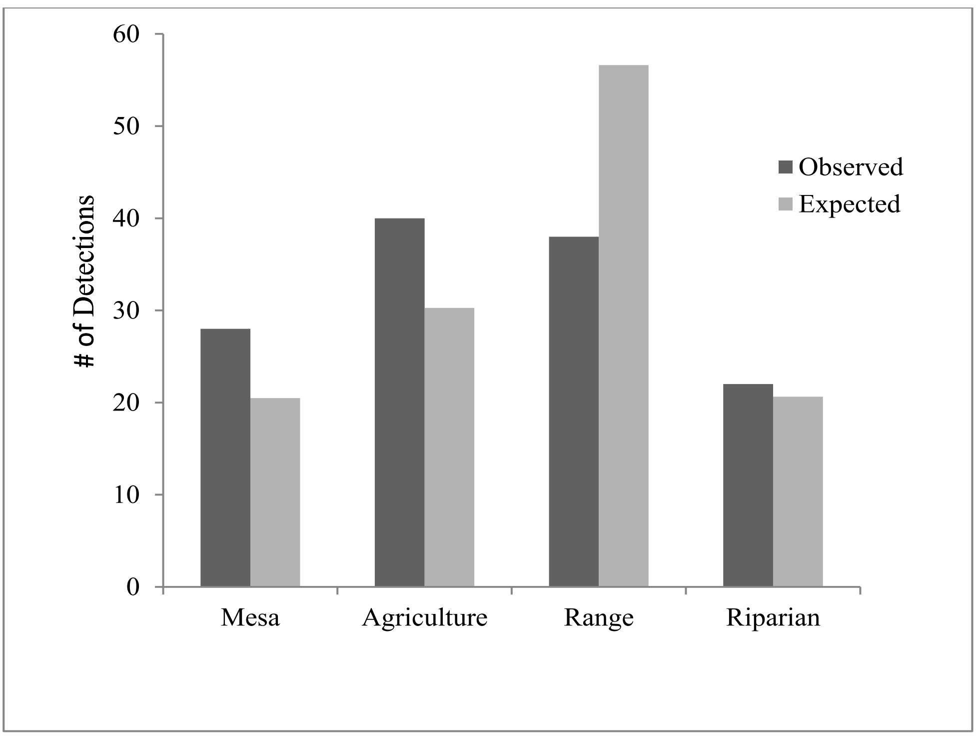

Figure 2 - All carnivore detections across habitats of the Oklahoma panhandle (p < 0.01).

swift foxes over the course of this study are discussed more extensively in Shaughnessy (2003). However, it is important to note that the swift fox is not detected in all counties or habitats equally. Swift foxes are detected more often in the westernmost parts of the Oklahoma panhandle and specifically in Cimarron County. Foxes are not detected as often as expected in

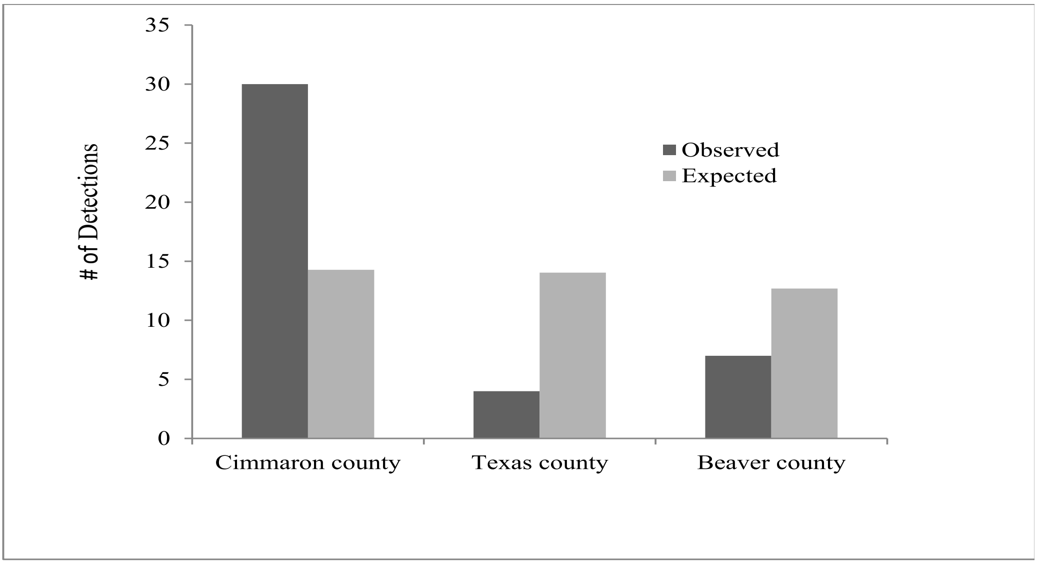

Figure 3 - Swift fox (*Vulpes velox*) detections across the Oklahoma panhandle counties ($p < 0.001$).

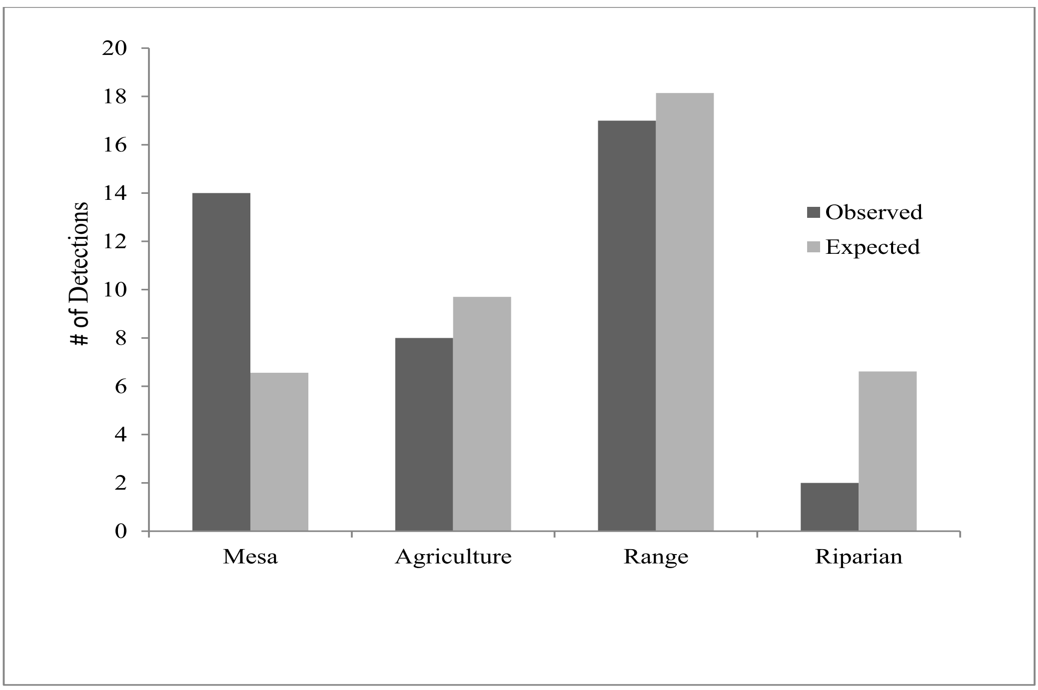

Figure 4 - Swift fox (*Vulpes velox*) detections across habitats of the Oklahoma panhandle ($p < 0.01$).

either Texas or Beaver counties. Additionally, swift foxes also demonstrate a clear preference for the westernmost physiographic regions of the panhandle (mesa and northwestern mesa/riparian) and are absent in the more centrally located regions of the panhandle (north/central agriculture and central mixed agriculture and range).

Patterns in coyote occurrence in the panhandle

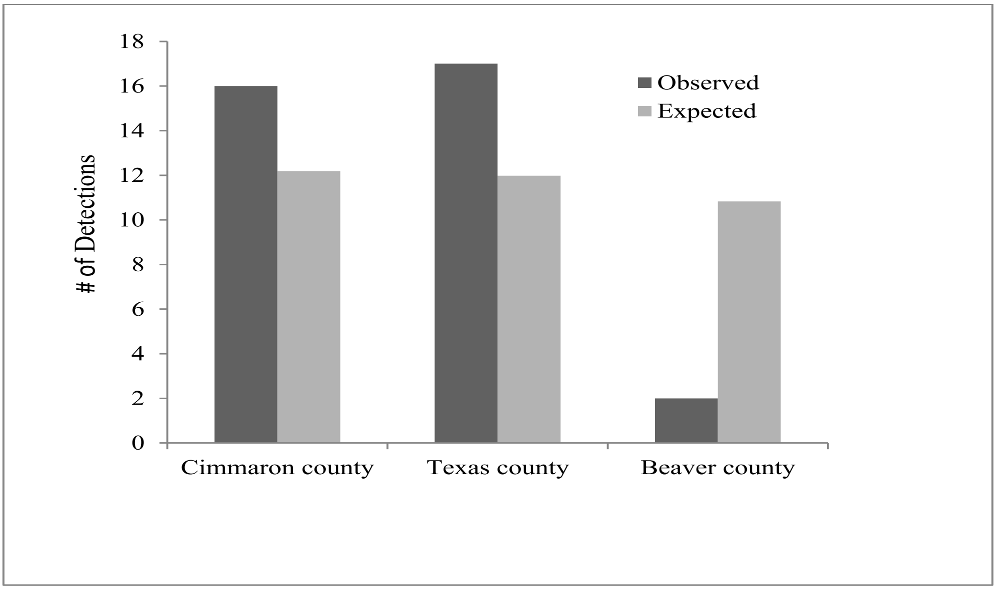

Figure 5 - Coyote (*Canis latrans*) detections across the Oklahoma panhandle counties (p < 0.01).

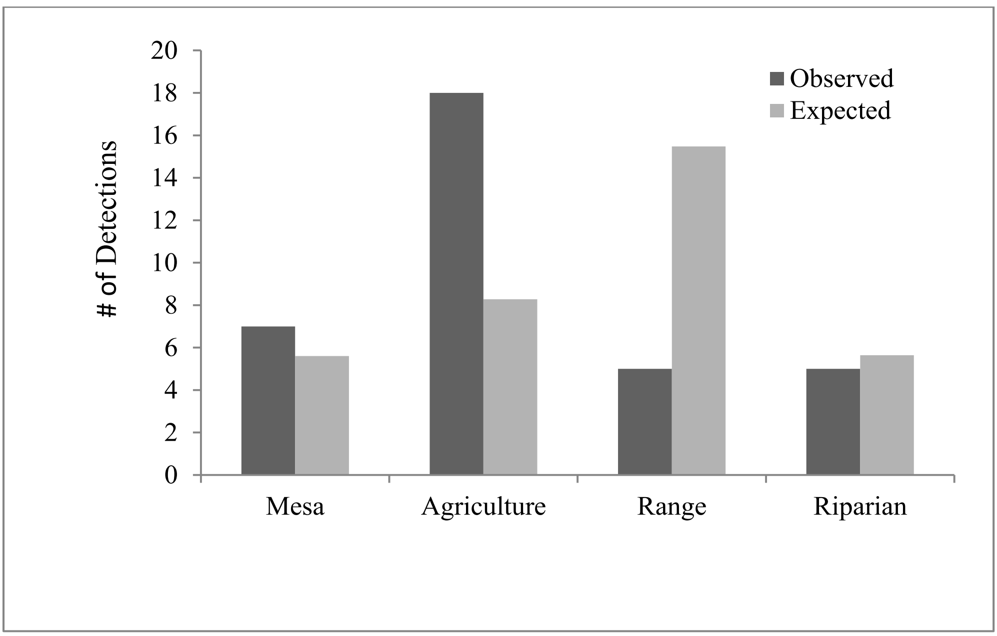

Figure 6 - Coyote (*Canis latrans*) detections across habitats of the Oklahoma panhandle (p < 0.001).

are similarly uneven. Coyotes are detected most often in Texas County. They are only rarely detected in Beaver County and they are detected about as often as expected in Cimarron County. Coyotes in Cimarron County are detected outside of the mesa region. Physiographically, coyotes prefer the north/central agricultural region of the panhandle far above any other panhandle region.

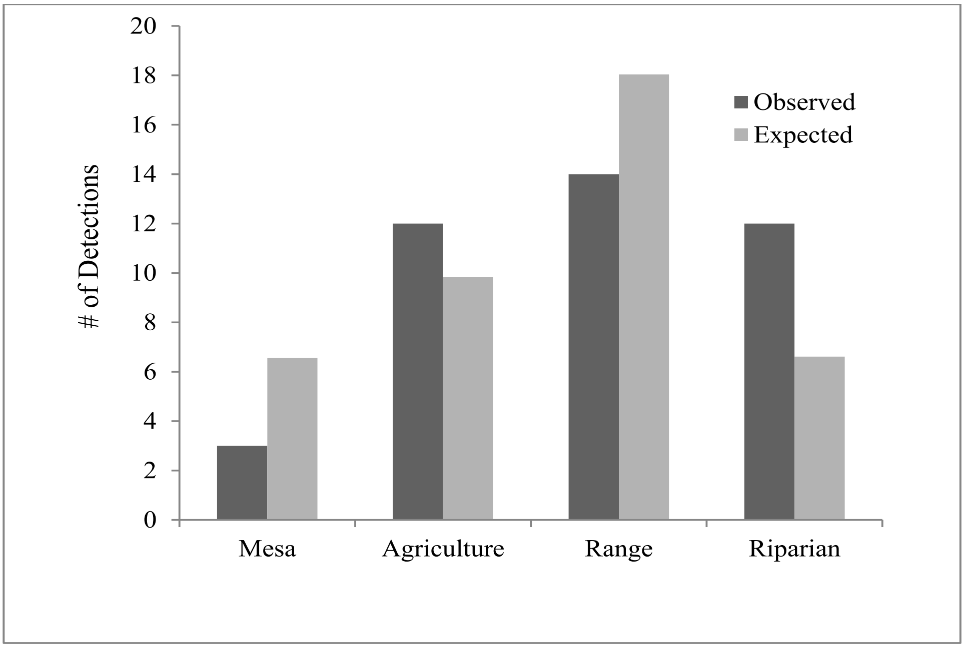

Figure 7 - Detections of mustelids and mephitids across habitats of the Oklahoma panhandle ($p < 0.05$).

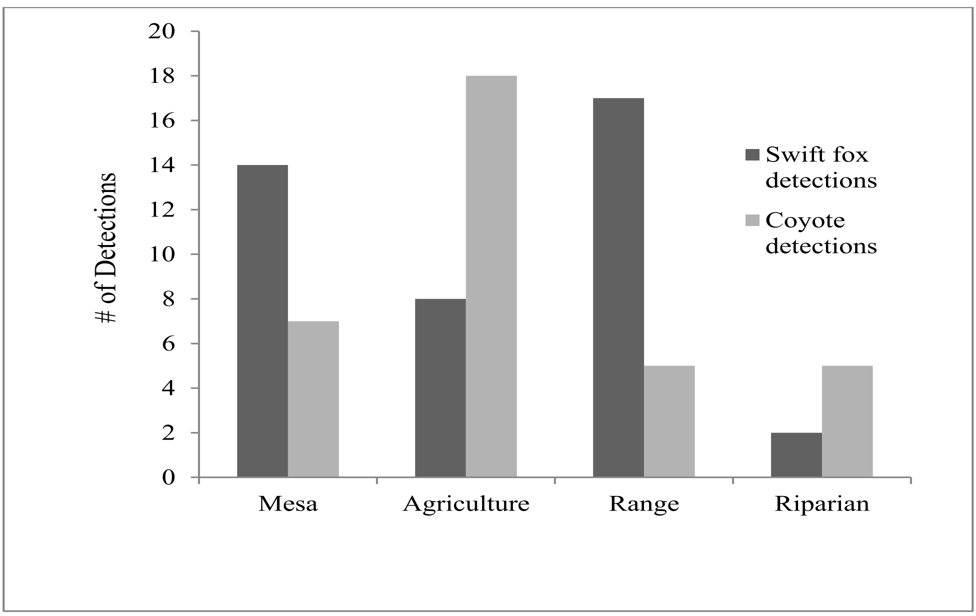

Figure 8 - Detections of swift foxes (*Vulpes velox*) and coyotes (*Canis latrans*) across habitats of the Oklahoma panhandle ($p < 0.005$).

They also occur regularly in the southwestern grassland region of the panhandle. Coyotes avoid the northwestern mesa/riparian region as well as the northeastern riparian/range area of the panhandle.

In habitats, coyotes prefer agricultural areas over all other areas. They are detected in agricultural areas more than twice as often as predicted (Figure 6). Coyotes are detected in riparian areas about as often as expected, but they apparently avoid mesa and range areas and are only recorded in these areas about half as much as expected (Figure 6). Given these habitat affinities for coyotes, it is not surprising that coyotes are detected most often in Texas County. Texas County is predominantly an agricultural county. Cimarron and Beaver counties are much less devoted to agricultural practices.

Canids as a group are also not distributed evenly across the panhandle, between counties or among macrohabitats. Canids are detected much more often than expected in Cimarron County and much less than expected in Beaver County. Canids display decreases in occurrence from west to east in the Oklahoma panhandle. Canids also show a preference toward the mesa and agricultural areas of the panhandle while exhibiting an aversion towards riparian and range areas. This result is probably due to the strong positive individual responses of swift foxes and coyotes toward each of these areas respectively.

Canid occurrences in the panhandle were determined to be governed at least in part by a strong interaction between the two species (Shaughnessy, 2003). Where coyotes occurred in abundance, swift foxes were conspicuously absent (Figure 8). Swift foxes are present in abundance only in those areas where coyotes are detected infrequently, most notably the mesa region (Figure 8). This strong negative interaction has been documented among other canid species (Carbyn 1982; Rudzinski et al. 1982; Sargeant et al. 1987; Harrison et al. 1989; Bailey 1992; Thurber et al. 1992; Peterson 1995; Johnson et al. 1996; Dayan and Simberloff 1996). Coyotes and other larger canids have been documented as significant sources of mortality for smaller canids and swift foxes, specifically in the prairie environment (Carbyn 1982; Rudzinski et al. 1982; Sargeant et al. 1987; Harrison et al. 1989; Bailey 1992; Peterson 1995; Johnson et al. 1996; Dayan and Simberloff 1996). This interaction between swift foxes and coyotes in the Oklahoma panhandle is, therefore, not surprising.

While the presence or absence of coyotes undoubtedly affects swift fox habitat selection in the Oklahoma panhandle, the interaction is probably not the sole determining factor in swift fox distribution. Swift foxes tend to be highly sensitive to predation from many potential predators, not only larger canids (Egoscue 1956, 1962, 1979). This susceptibility to predation also is inferred by the swift fox's heavy reliance on den sites and subterranean tunnels (Egoscue 1962, 1979; Moehrenschlager 2003). Tall grass areas may inhibit the ability of the swift fox to detect predators because of the fox's small size (Allardyce pers. comm.). Tall grass areas also may limit the ability of the fox to find a suitable escape route underground when confronted with a predator (Allardyce pers. comm.). Swift foxes may be avoiding tall grass areas to facilitate predator detection and escape (Allardyce pers. comm.).

The mesa areas are dominated by shorter grasses that the foxes may prefer because they allow them to more easily detect predators and locate escape routes underground. Additionally, agricultural areas are only seasonally planted and often left fallow, with only low ground plants covering them. Swift foxes may be using agricultural areas because their normally low vegetation aids them in predator avoidance, and persisting in agricultural areas during the short periods of time when crops are tall. Conversely, range/grassland areas are often a mix of tall grass areas, short grass areas, and areas that are barren due to overgrazing. The absence of coyotes in these areas (Figure 6) may be attractive to swift foxes, but the heterogeneous nature of the habitat, particularly the presence of tall grasses, may discourage selection of this habitat by swift foxes. This may explain the slightly depressed occurrence frequency of swift foxes in range/grassland areas (Figure 4). Finally, swift foxes are absent from riparian areas. These areas are often overgrown with tall grasses, shrubs, bushes, and trees. In addition, coyotes are found in abundance riparian areas (Figure 6). It is not surprising then, that swift foxes are uncommon in riparian areas.

Coyote occurrence patterns are not easily explained. Coyotes exhibit no aversion to riparian areas and an overwhelming preference for agricultural areas (Figure 6). Coyotes are among the largest terrestrial predators in the Oklahoma panhandle and are the largest carnivores detected during this study. Riparian areas often serve as travel corridors for a variety of panhandle vertebrates. Coyotes may be frequenting riparian areas to increase the probability of encountering potential prey. Agricultural areas may support higher numbers of small and medium-sized mammals. Rodent populations may be higher in agricultural areas than in the surrounding grasslands due to the seasonal abundance of seed resources. Coyotes may prefer agricultural areas because of their potential for higher rodent resource bases.

Coyote habitat selection may also be influenced by human factors in the Oklahoma panhandle. Coyotes did not occur often in mesa or range/grassland areas (Figure 6). Much of the range/grassland and mesa areas of the panhandle are used for cattle production (Shaughnessy 2003). Coyotes are considered significant predators on livestock by the ranchers in the Oklahoma panhandle and substantial effort is invested in coyote control in the primary cattle production areas (Shaughnessy 2003). Coyote populations may be reduced in these areas due to these control efforts, and coyotes may be selectively avoiding these areas in response to the control efforts (Shaughnessy 2003).

An additional historical component may be at work in the dynamics of panhandle canid populations. The wolf (*Canis lupus*) historically occupied the Oklahoma panhandle (as well as the body of the state). Antagonistic interactions between coyotes and wolves are well documented (Carbyn 1982; Thurber et al. 1992; Peterson 1995). It is possible that the wolf historically structured the panhandle canid community by eliminating coyotes from local areas and limiting their populations regionally. If this were the case, the interaction would have benefitted swift foxes and other smaller canids. With the extirpation of wolves, however, coyote numbers have not only increased, but coyotes have invaded habitats from which they were previously excluded by wolves. As a result, it is likely that coyotes now eliminate swift foxes locally and swift foxes are only able to thrive in those habitats that coyotes do not prefer.

Mustelids/Mephitids

Of the three mustelid species that were detected during the course of this study, spotted skunks were detected most often. Overall, spotted skunks were detected most often in Cimarron County and least often in Texas County. However, these differences are not statistically significant. Physiographically, spotted skunks also occur evenly among all designated regions. While power for the habitat test was low, power for the county test was high. Given that the two tests agreed, the probability of the commission of a Type II error seems remote. As a result, we conclude there are no regional biases in spotted skunk detections throughout the panhandle.

Badgers were detected regularly throughout the course of the study as well, but not with the frequency of spotted skunks. Badgers were detected much more often in Cimarron County than in any other panhandle county, however these differences are not significant. Power for this test was high as well, so although there are detection differences between counties, no regional preference exists.

Striped skunks were detected least often over the course of this study. Striped skunks are distributed very evenly across the three panhandle counties. Statistical power is low, however, for this test, so these results should be interpreted with caution. Striped skunks show significant habitat preferences within the counties. Striped skunks markedly prefer riparian areas over all other panhandle habitats. They also occur regularly in the mesa and agricultural areas, but are under-represented in grassland/range areas.

Mustelids and mephitids in general are distributed evenly across the entire panhandle, although power is low for this test. Due to the low power, results should again be interpreted with caution and trends in occurrences should be examined. Mustelids/mephitids were detected more often in Cimarron County than in either Texas or Beaver counties. Mustelids/mephitids were detected in Cimarron County twice as often as they were detected in Texas County and nearly twice as often as they were detected in Beaver County. Mustelids/mephitids exhibit clear habitat preferences in the Oklahoma panhandle. Mustelids/mephitids prefer riparian and agricultural areas over other habitats in the panhandle (Figure 7). They do not appear to avoid the mesa area, but do show a clear aversion to the range/grassland areas of the panhandle. Mustelids and mephitids also do not demonstrate any significant intra- or interfamilial interactions.

Mustelid/mephitid distribution patterns in the Oklahoma panhandle are more difficult to explain due to the lack of intra- and interfamilial interactions. Intraorder level interactions are present among all canids and mustelids/mephitids, however. Mustelids/mephitids tend to avoid those habitats which support higher numbers of swift foxes and are generally more abundant in areas with higher coyote occurrences. Although swift foxes are generally larger than the these mesocarnivores, it seems unlikely that the dynamics defining swift fox/coyote interactions and distributions are at work between swift foxes and badgers/skunks owing to the defensive adaptations of skunks and the generally aggressive disposition of badgers. It seems more likely to us that mustelids and mephitids, like coyotes, are simply selecting areas that may support larger small-mammal and, in particular, rodent populations such as agricultural areas.

Small canids tend to be more generalized in their food habits than larger canids (or mustelids) and are able to persist on a less strictly carnivorous diet (Cutter 1958; Johnson et al. 1996). If coyotes exclude swift foxes from areas of high rodent densities, swift foxes should be able to persist in less optimal areas (in terms of rodent densities) by expanding their diet to include a wider variety of foods. Mustelids and mephitids, by virtue of their defenses and smaller size, are probably not viewed by coyotes as being strong food resource competitors. Mustelids/mephitids are also more strictly carnivorous than canids (Feldhamer et al. 1999). They would be predicted to select areas with the highest prey bases available. This may explain the similar habitat selections by coyotes, badgers and skunks if agricultural areas do indeed support higher small mammal populations than surrounding habitats.

Felids

The final carnivore detected during this study was the bobcat. Bobcats were only detected infrequently. Bobcats are distributed evenly among counties. In the panhandle, bobcats are also distributed evenly among habitats. The relative scarcity of data for cats in general underscores the need for further research on the role of felids in the Oklahoma panhandle carnivore community.

Discussion

Overall, carnivores are not distributed evenly throughout the panhandle or among habitats. Panhandle distributions may be indirectly related to human populations and activities. Carnivores were overwhelmingly detected more often in the western third of the panhandle (Cimarron County), with detections tending to decrease eastward through the panhandle. Cimarron County is the least populated and developed county in the Oklahoma panhandle. Human populations steadily increase eastward to Guymon, Oklahoma, which is located in the center of Texas County, in the very middle of the panhandle. Human populations then slightly decrease through Beaver County, which may also explain some of the far eastern distributional peaks in carnivore occurrences. Carnivore habitat preferences are often also dependent upon the presence or absence of other carnivores and may be dependent upon relative densities of small mammals within habitats. However, more research in the form of small mammal surveys in the major panhandle habitats is needed to properly address this hypothesis.

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