An Assessment of Habitat Fragmentation by Roads in Cimarron County, Oklahoma

Brandi S. Coyner
Department of Zoology, Oklahoma State University, Stillwater, OK 74078

Cimarron County, Oklahoma, is a relatively unpopulated county in the Oklahoma panhandle where 5 native habitat types occur, which has resulted in an elevated vertebrate diversity in comparison to the surrounding counties. Anthropogenic effects have led to a network of roads resulting in the dissection of native habitat types. A Geographic Information Systems (GIS) analysis was conducted to evaluate changes in patch number, mean patch size, maximum patch size, and total patch perimeter for each native habitat type occurring in Cimarron County. Results indicated significant habitat fragmentation in the most widespread native habitat type (grama-buffalograss prairie) and moderate to insignificant fragmentation in the other four native habitat types.

Human-induced habitat fragmentation has been identified as a major threat to the conservation of endangered and threatened organisms (1). Most commonly such human-induced fragmentation occurs as the conversion of native habitats to cropland or urban regions, the destruction of habitats such as deforestation or wetland removal, or the division of habitats through the construction of dams, roads, or other barriers. Human-induced habitat fragmentation unnaturally decreases patch size, increases patch perimeter to area ratios, isolates populations, and can increase human-wildlife interactions along habitat edges.

Arguably the greatest human-induced habitat fragmentation has come in the network of roads that crisscross human-inhabited landscapes. Not only have road and highway networks been shown to have negative effects on multiple groups of organisms by increasing habitat fragmentation and decreasing habitat and habitat quality, they have also been shown to affect animal behavior, impair movement, and increase mortality due to road traffic (2, 3). Although studies have evaluated the impacts of roads and traffic on organisms, few have quantified the fragmentation of habitats by roads (amphibians – 4; birds – 5; invertebrates – 6; mammals – 7).

Human dependency on vehicular transportation makes it unlikely that road construction will halt in the near future. As the human population increases, demand will likely increase for road construction of large highway networks. As we face the probable extinction of many organisms, the ecological impact of roads will need to be considered before roads are constructed. An understanding of how current roads affect and fragment habitats will be critical. Therefore, the objective of this study was to quantify the fragmentation of habitats in an Oklahoma county by evaluating current fragmentation levels with roads in comparison to the same fragmentation without roads. For a given habitat, fragmentation by roads will manifest in an increased patch number, decreased mean and maximum patch area, and an increased total patch perimeter as compared to the habitat without roads overlaid.

METHODS

Study Area

Cimarron County (Fig 1; lat 36.75°N, long 102.40°W) is the westernmost county in the panhandle of Oklahoma and encompasses 475,263 hectares (ha) of land and 1,554 ha of water. Cimarron County is relatively unpopulated (3,148 in 2000; 1.7 persons per

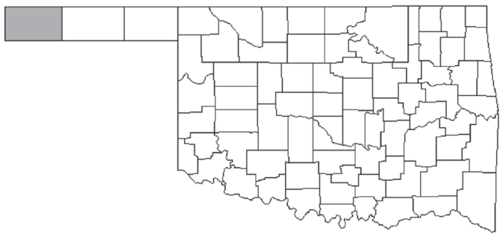

Figure 1. Map of the state of Oklahoma with Cimarron County highlighted.

square mile) and was estimated to decrease an additional 10% from 2000 to 2005 (8). The county has two incorporated cities (Boise City and Keyes) and seven named communities with no censused population. The roads of Cimarron County include class II, III, IV, and V roads and are dominated by dirt roads, residential-access roads, and small through-streets (classes IV and V).

Cimarron County is home to Black Mesa, Oklahoma's highest point, in the extreme northwestern part of the county and partially contains the Piñon-Juniper Mesas and Shortgrass High Plains physiognomic regions (9). Approximately 30% of the county's landscape is cropland, improved pasture, designated for urban or other agricultural use, or covered by naturally occurring water (10). The remaining 70% falls into one of five habitat type categories: western bottomland forest, one-seed juniper woodland, grama-buffalograss prairie, sandsage prairie, and sandsage savanna (Table 1; 10).

In general, total vertebrate species richness decreases from east to west, being highest in the forests and tall grass prairies of the east and lowest in the short grass prairies of the west with the lowest species richness occurring in the panhandle. Cimarron County is anomalous in that it has an increased local richness in comparison with the rest of the panhandle and other shortgrass prairie regions (Fig. 2; 10).

Data Analyses

Digitized land cover data for the state of Oklahoma was available as GIS layer data

Table 1. Defined cover types of Cimarron County. Cover types were modified from Fisher and Gregory 2001.

Land Cover	Description	% County
Western Bottomland Forest	Cold deciduous alluvial forest dominated by *Populus deltiodes*, *Ulmus americana*, and *Celtis* spp.	0.13%
One-seed Juniper Woodland	Evergreen needle-leaved woodland with rounded crowns dominated by *Juniperus monospermata*	1.39%
Grama-buffalograss Prairie	Short grass community composed mainly of sod grasses dominated by *Bouteloua gracilis*, *Buchloe dactyloides*	55.93%
Sandsage Prairie	Evergreen microhpyllus shrubland dominated by *Artemisia filifolia*, *Schizachyrium scoparium*, *Andropogon gerardii*	1.73%
Sandsage Savanna	Shrub layer of mainly microphyllus evergreen shrubs *Artemisia filifolia*, *Buchloe dactyloides*, *Bouteloua gracilis*	11.19%
Urban/Agricultural Use	Developed lands including urban areas, agricultural fields, croplands, and pastures	29.29%
Water	Lakes, reservoirs, and rivers	0.33%

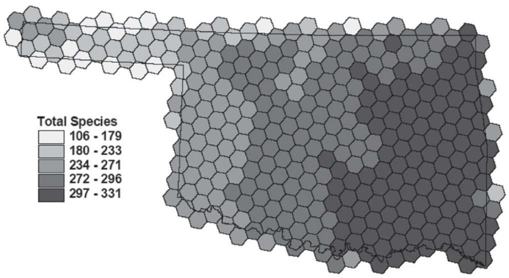

Figure 2. Total vertebrate species richness for the state of Oklahoma (10).

from the Gap Analysis Project (10). Original data for the Gap Analysis was based upon Landsat TM satellite data with a resolution of 30 meters. Digitized road data for the state was obtained from the Oklahoma Center for Geospatial Information (Department of Geography, Oklahoma State University, Stillwater, OK). All digitized layers were imported into ArcGIS 9.1 (ESRI, San Antonio, Texas) where statewide data were clipped to include only Cimarron County. The habitat class water was reclassified as null to prevent the analysis from fragmenting habitats by rivers and ponds, which are assumed to be natural features of the landscape and not necessarily fragmenting features.

A vector file for habitat fragmented by roads was created by overlaying the vector shapefile for roads over the digitized land cover data layer. Vector shapefiles of the habitat and the habitat fragmented by roads (Figure 3) were imported into ArcView 3.3 (ESRI, San Antonio, Texas). Patch Analyst, an ArcView 3.3 extension based upon the free-standing program FRAGSTATS (11), was used to determine patch number, mean patch size, maximum patch size, and total patch perimeter for each habitat type in both the landscape lacking roads and the landscape overlaid with roads. Results were recorded only for native habitats (western bottomland forest, one-seed juniper woodland, grama-buffalograss prairie, sandsage prairie, and sandsage savanna). Fragmentation of urban, agricultural, or aquatic habitats by roads was not considered.

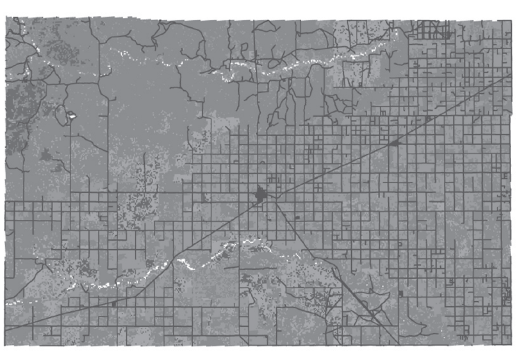

Figure 3. Digitized landscape of Cimarron County overlaid by roads.

The analysis was repeated to evaluate the fragmentation of total native habitat by roads to remove fragmentation of one class of native habitat by another class of native habitat (i.e. sandsage savanna fragmented by grama-buffalograss prairie), justified under the assumption that such fragmentation is *natural fragmentation*. The five native habitats (western bottomland forest, one-seed juniper woodland, grama-buffalograss prairie, sandsage prairie, and sandsage savanna) were reclassified to the same value. Results were recorded for the four patch parameters calculated with and without roads.

RESULTS

The obtained values for each of the four patch parameters determined for the five native habitat types are summarized in Tables 2–4. The introduction of roads caused number of patches to increase in one-seed juniper woodland and grama-buffalograss prairie by 3 and 825, respectively, whereas patch number decreased in western bottomland forest by 1 patch, in sandsage prairie by 36 patches, and in sandsage savanna by 53 patches.

DISCUSSION

In Cimarron County, Oklahoma, roads are changing native habitat patch parameters, but changes are inconsistent across the five native habitats. Across all five native habitats, roads do not significantly alter the four considered habitat class patch parameters (Table 2). However when each habitat class is considered before and after road-overlay, differences are noticeable (Tables 3–4).

Of the five habitat classes considered, only grama-buffalograss prairie appears to be fragmented by roads. Grama-buffalograss prairie represents a majority (55.93%) of the total area of Cimarron County. It accounts for nearly all native habitat in the eastern one-half of the county and seems to be the habitat most likely to neighbor agricultural or urban use land where roads are concentrated. Because grama-buffalograss prairie covers a significantly larger area and occurs in close proximity to human-altered habitats, there may be a bias toward greater fragmentation in grama-buffalograss prairie in comparison to the other four native habitat classes.

One-seed juniper woodland habitat covers only a small portion (1.39%) of the county and is isolated in the western part of Cimarron County where no-incorporated cities occur and where few people live. The northwestern part of the county is more geologically variable, with rocky outcroppings and a number of mesas, than the rest of the county, making this area less appealing for cropland and more difficult and financially costly to construct roads. Therefore, the one-

Table 2. Patch parameters of combined native habitat types with and without fragmentation by roads.

	Without Roads	With Roads
Number of patches	1831	2601
Mean patch area (ha)	138	3514.43
Maximum patch area (ha)	3874	69469.50
Total Patch Perimeter (km)	658	526.03

Table 3. Patch parameters of 5 native habitat types in Cimarron County, Oklahoma.

	Without Roads			
	Number of patches	Mean Patch Area (ha)	Maximum Patch Area (ha)	Total Patch Perimeter (km)
Western Bottomland Forest	89	6.55	46.17	92.97
One-seed Juniper Woodland	135	49.83	3691.43	409.66
Grama-Buffalograss Prairie	3049	88.76	142349.42	10686.75
Sandsage Prairie	694	10.86	608.53	908.30
Sandsage Savanna	2630	19.54	4943.93	4433.19

Table 4. Patch parameters of 5 native habitat types fragmented by roads in Cimarron County, Oklahoma.

	With Roads			
	Number of patches	Mean Patch Area (ha)	Maximum Patch Area (ha)	Total Patch Perimeter (km)
Western Bottomland Forest	88	6.42	46.16	91.02
One-seed Juniper Woodland	138	47.48	3514.43	408.44
Grama-Buffalograss Prairie	3874	59.33	69469.50	11145.10
Sandsage Prairie	658	11.02	526.03	869.39
Sandsage Savanna	2577	18.08	2419.56	4229.39

seed juniper woodland habitat occurring in Cimarron County is unlikely to have roads occur within it and therefore unlikely to be fragmented significantly by roads.

Western bottomland forest and sandsage prairie cover small areas, 0.13% and 1.73%, respectively, and occur in numerous small patches before roads are superimposed over the natural landscape. Western bottomland forest occurred in only 88 patches of 6.55 ha/patch without roads and is limited to riverine habitats making it considerably fragmented prior to overlaying of roads. Sandsage savanna was also considerably fragmented with nearly 700 patches averaging only 10.86 ha/patch. Therefore, additional fragmentation of the already small isolated patches within the western bottomland forest and sandsage prairie was insignificant.

Sandsage savanna is the second most common native habitat occurring in Cimarron County, Oklahoma, comprising 11.19% of the landscape. Overall, roads do not fragment sandsage savanna, but a significant change in maximum patch size occurred with the division of the single largest patch (4943.93 ha), which was reduced to 2419.56 ha with roads overlaying the habitat. Sandsage savanna also consisted of a large number of small patches prior to road overlay making additional fragmentation of these patches unlikely.

In three of the classes (western bottomland forest, sandsage prairie, and sandsage savanna), patch number decreases indicating that perhaps the most significant change by roads in these habitats is loss of habitat and not fragmentation of habitat. Cumulatively, the low road density in Cimarron County results in the fragmentation of common habitat types and large patches of any habitat type but leaves rare or isolated patches unaffected by roads.

CONCLUSION

Natural features such as streams, geologic features, and remnant patches fragment native habitats. Seen as a positive, this natural fragmentation creates heterogeneity and variability increases the number of available ecological niches. Between positive habitat heterogeneity and negative habitat fragmentation exists a theoretical threshold. In most cases, this theoretical threshold is crossed when humans enter an area and alter the landscape by converting native habitat to agricultural or urban use land or by erecting barriers that divide native habitats.

Most notably, humans have constructed a massive network of roads and interstates that crisscross nearly every habitat on Earth. These roads represent hard and soft barriers with many merely acting as filters for certain species. For example whereas a multilane thoroughfare may act as a barrier for all terrestrial species, a paved country road may only hinder small species slightly and leave larger ones totally unaffected. Likewise a patch of converted habitat such as a wind farm acts as a large hindrance to aerial organisms but may not affect terrestrial organisms at all. Therefore when considering the fragmentation of habitat, it is likely most important to determine what one is trying to conserve and then determine what acts as a barrier (i.e. habitat fragmenter) to that species, population, or community. This will allow for the best conservation strategy and will not complicate the situation with insignificant problems and non-existent barriers.

ACKNOWLEDGMENTS

The NSF Graduate Research Fellowship Program provided stipend and educational support while this project was completed. I would like to thank T. J. O'Connell, S. D. Fuhlendorf, and D. E. Shoup for statistical assistance and comments.

REFERENCES

(1) Fahrig L, Merriam G. 1994. Conservation of fragmented populations. Conserv Bio. 8:50–59.

(2) Spellerberg IF. 1998. Ecological effects of roads

and traffic: a literature review. Glob Ecol Biogeog 7:317–333.

(3) Trombulak SC, Frissell CA. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conserv Biol 14:18–30.

(4) Vos, C. C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog Rana arvalis. J Appl Ecol 35: 44–56.

(5) Mumme RL, Schoech SJ, Woolfenden GE, Fitzpatrick JW. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. Conserv Biol 14:501–512.

(6) Keller I, Nentwig W, Largiader CR. 2004. Recent habitat fragmentation due to roads can lead to significant genetic differentiation in an abundant flightless ground beetle. Mol Biol 13:2983–2994.

(7) Mace RD, Waller JS, Manley TL, Lyon LJ, Zuuring H. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. J Appl Ecol 33:1395–1404.

(8) United States Bureau of the Census. 2000. Census of population and housing. [on-line]. Available from: http://www.census.gov/. (Accessed February 5, 2008).

(9) Caire W, Tyler JD, Glass BP, Mares MA. 1989. Mammals of Oklahoma. Norman (OK): University of Oklahoma Press. 565 p.

(10) Fisher, WL, Gregory MS. 2001. Oklahoma Gap Analysis Project: a geographic approach to planning for biological diversity. USGS Report 1–771.

(11) McGarigal K, Cushman SA, Neel MC, Ene E. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at: www.umass.edu/landeco/research/fragstats/fragstats.html.

Received: May 15, 2008; Accepted November 21, 2008.