# INFLUENCE OF ROADS AND LANDSCAPE FEATURES ON THE SPATIAL ECOLOGY AND MORTALITY OF OCELOTS IN SOUTH TEXAS

A Thesis

by

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# ABSTRACT

Influence of Roads and Landscape Features on the Spatial Ecology and Mortality of Ocelots in South Texas

(August 2020)

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Urban development is the leading cause of habitat loss, replacing natural areas with infrastructure and road networks. Roads can negatively impact wildlife populations through habitat fragmentation, decreased landscape connectivity, and wildlife-vehicle collisions. Ocelots (*Leopardus pardalis*) are a federally endangered felid, with the sole breeding populations in the United States restricted to the Lower Rio Grande Valley of South Texas, an area of extensive anthropogenic expansion. Vehicle collisions are the highest sources of mortality for ocelots in Texas. Mitigation strategies, such as wildlife crossing structures, have been implemented throughout South Texas in the last 3 decades to combat the negative effects of roads on the ocelot populations. However, there has only been 1 documented case of an ocelot using a road crossing structure. The goal of my project was to analyze ocelot landscape use and response to road networks to inform potential locations for future road crossing structures designed for ocelot recovery. I examined the landscape structure surrounding ocelot-vehicle collision sites to understand the relationship between the spatial structure of land cover and where ocelots are

struck by vehicles. I also examined the landscape structure surrounding wildlife crossing structures implemented for ocelot use to understand potential reasons ocelots may not use the structures. Lastly, I evaluated the relationship between biological and road-related factors and ocelot mortality risk, to determine which factors contribute to the probability of mortality from vehicle collision. Results from this study will improve conservation efforts for the endangered ocelot by illustrating the need for strategies to mitigate vehicle collisions and improve landscape connectivity. These results can be used for the placement of future road crossing structures more likely to be used by ocelots.

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All other work conducted for the thesis was completed by the student independently.

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## NOMENCLATURE

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| AI | Aggregation Index |
| ED | Edge Density |
| ENN | Euclidean Nearest Neighbor |
| LPI | Largest Patch Index |
| LANWR | Laguna Atascosa National Wildlife Refuge |
| LRGV | Lower Rio Grande Valley |
| MPA | Mean Patch Area |
| PD | Patch Density |
| PLAND | Percent Land Cover |
| PMDI | Palmer Modified Drought Index |

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CHAPTER I

# LANDSCAPE PATTERNS OF OCELOT-VEHICLE COLLISION SITES[1]

**ABSTRACT** Road networks can negatively impact wildlife populations through habitat fragmentation, decreased landscape connectivity, and wildlife-vehicle collisions, thereby influencing the spatial ecology and population dynamics of imperiled species. The ocelot (*Leopardus pardalis*) is a federally endangered wild felid in South Texas, with a high mortality rate linked to vehicle collisions. This study examined the spatial structure of land cover in relation to ocelot road mortality locations. I quantified the spatial distribution of land cover types at 26 ocelot-vehicle collision sites in South Texas that occurred from 1984–2017. I compared landscape metrics of woody, herbaceous, and bare ground cover types across multiple spatial scales at roadkill locations to those from random road locations, and between male and female ocelots. Road mortality sites consisted of 13–20% more woody cover than random locations. Woody patches at road mortality sites were 7.1–11% larger (2.4 ha) closer to roads, and spaced 10–16 m closer together at distances farther away from roads compared to random locations. Percent woody cover was the best indicator of ocelot-vehicle collision sites; there were no differences in woody cover between male and female road mortality locations. These findings suggest that ocelots are likely struck by vehicles while crossing between habitat patches. Roads that bisect areas of woody cover have negative impacts on ocelots by increasing habitat fragmentation and vulnerability to vehicle collisions. These results can be used to inform the placement of future crossing structures or other mitigation strategies, thus reducing ocelot-vehicle collisions.

[1] *Formatted to Landscape Ecology*

**KEY WORDS** landscape ecology, ocelot, road mortality, wildlife-vehicle collisions, wildlife crossing structures.

Roads can negatively impact survival and movements of wildlife, including reptiles and amphibians (Marsh et al. 2005; Shephard et al. 2008), birds (Laurance et al. 2005), and mammals (Oxley et al. 1974; Groot Bruinderink and Hazebroek 1996). Negative impacts may be direct, due to vehicle collisions and physical barriers to movement, or indirect, when roads act as functional barriers that reduce gene flow and reproductive success (Harris and Scheck 1991; Forman and Alexander 1998; Smith and Dodd 2003; Riley 2006; Litvaitis et al. 2015). Roads are often the principal threat to successful dispersal of wildlife within urban areas (Forman and Alexander 1998), and vehicle collisions have become an increasing source of wildlife mortality as transportation infrastructure increases because of urban sprawl (Forman et al. 2003). Road mortality has impacted population demographics of species of conservation concern (e.g., Kerley et al. 2002; Cypher et al. 2009), and population sizes of threatened or endangered species, including the Florida panther (*Puma concolor coryi*) and Key deer (*Odocoileus virginianus clavium*;Evink et al. 1996; Land and Lotz 1996). However, little research has evaluated how the spatial structure of landscape features around roads influences vehicle collisions. This information is critical for the conservation of imperiled species.

The spatial structure of land cover types can dictate animal space use, movement, and abundance (Thornton et al. 2011; Baigas et al. 2017; Marchand et al. 2017). For example, an evaluation of landscape spatial structure is useful in the assessment of habitat fragmentation for wild felids (Jackson et al. 2005; Zemanova et al. 2017). However, the relationship between landscape structure and road mortality patterns remains largely unknown for many species, particularly those threatened or endangered. Studies suggest wildlife-vehicle collisions are often spatially aggregated (Main and Allen 2002), and occur along roadways near natural vegetation cover (Romin and Bissonette 1996; Clevenger et al. 2003). Further, many ecological patterns are influenced by elements acting at multiple spatial scales (Weins 1989; Bauder et al. 2018). The spatial scale at which a landscape feature has the strongest effect on species response (e.g., movement, abundance) is termed the "scale of effect;" although the "scale of effect" varies with the response variable, it does not always vary in a predictable manner (Jackson and Fahrig 2012; Moraga et al. 2019). Without previous multi-scale studies to base analyses of the effects of landscape structure on wildlife behavior, it is recommended to estimate the "scale of effect" empirically using a multi-scale study design (Moraga et al. 2019). Understanding landscape patterns and spatial scale associated with wildlife-vehicle collisions can inform mitigation strategies for sensitive species within a fragmented landscape.

The ocelot (*Leopardus pardalis*) is a medium-sized neotropical felid that is listed as endangered at the state and federal levels in the United States (U.S.; USFWS 1982; TPWD 2018). Fewer than 80 ocelots remain in the U.S. (Tewes 2019), divided between 2 isolated breeding populations in the eastern Coastal Sand Plain and the Lower Rio Grande Valley of Texas (Janečka et al. 2011; Janečka et al. 2016). Ocelots in this region are habitat specialists with spatial patterns strongly linked to dense thornshrub (Harveson et al. 2004). Ocelots select for areas with ≥75% thornshrub canopy cover, with a strong preference for habitat with >95% canopy cover (Horne et al. 2009). This dense thornshrub cover type used by ocelots is uncommon throughout the southernmost 13 counties of Texas, as an estimated <1% of this area presently contains suitable ocelot habitat (Tewes and Everett 1986).

During the past century, the Lower Rio Grande Valley has been substantially modified by urban development and agriculture (Leslie 2016). Native woodland declined 91% between the 1930s–1980s due to the expansion of agriculture and urban development (Tremblay et al. 2005). Urban expansion in this region has increased anthropogenic infrastructure, including housing developments, shopping centers, and road networks (Tiefenbacher 2001; Lombardi et al. 2020a). As the human population of this region grows, urbanization will become the primary driver of fragmentation and loss of native habitat (Marzluff and Ewing 2001; Lombardi et al. 2020a). Vehicle collisions represent the highest source of direct mortality for ocelots in this region (Haines et al. 2005). Thus, the challenge for ocelots to survive in an increasingly fragmented landscape is further exacerbated by the development and expansion of road networks to meet urbanization demands.

Few studies have examined the spatial structure of land cover of South Texas that may influence ocelot movement and dispersal (Harveson et al. 2004; Jackson et al. 2005). The identification of patterns in the landscape structure associated with ocelot-vehicle collisions at the appropriate scale can help precisely determine critical locations where ocelots may be vulnerable to vehicle-caused mortality. This information can then be integrated into mitigation strategies. The goal of this study was to understand the scale of effect of landscape structure associated with ocelot-vehicle collisions and aid conservation planners in the development of mitigation strategies. My main objectives were (1) to quantify the spatial distribution of land cover types at ocelot-vehicle collision locations, (2) to determine the scale at which spatial patterns of land cover at ocelot-vehicle collision locations differ from landscape spatial structure across my study area, and (3) to compare spatial structure of landscape features at vehicle collision sites between male and female ocelots.

## METHODS

Study area

My study area is located in the 3 southernmost coastal counties of Texas: Cameron, Kenedy, and Willacy (Fig. 1.1). Ocelots reside in 2 isolated breeding populations within these counties (Tewes and Everett 1986; Janečka et al. 2016). The southernmost ocelot population, the "Refuge Population", occurs in and around the Laguna Atascosa National Wildlife Refuge (26.2289° N, 97.3467° W), a federally protected area in Cameron County. The northernmost population, the "Ranch Population", occurs on private lands primarily in Kenedy and Willacy counties (Tewes 2019; Lombardi et al. 2020b). The region represents a transition zone between temperate and tropical conditions, with humid subtropical and semiarid climates, resulting in hot summers and mild winters (Leslie 2016). Rainfall fluctuates seasonally and among years, with an annual average of 660 mm (Norwine and John 2007). This region is in the Tamaulipan Biotic Province, constituting of hardwood and dense thornshrub forest. Dominant woody vegetation includes Texas ebony (*Ebenopsis ebano*), honey mesquite (*Prosopis glandulosa*), spiny hackberry (*Celtis pallida*), live oak (*Quercus virginianus*), lime prickly ash (*Zanthoxylum fagara*), huisache (*Acacia farnesiana*), and Texas lantana (*Lantana horrida*, Harveson et al. 2004; Leslie 2016).

*Landscape Analysis*

There were 50 recorded ocelot-vehicle collisions in the Lower Rio Grande Valley during 1982–2017. Of those records, 32 had documented geographic coordinates. The spatial accuracy of 2 road mortality locations did not fall on a road and were removed from analysis. Four ocelot-vehicle collisions were within completely urbanized areas; initial data analysis indicated these were aberrations compared to other mortality locations, thus were not included in the analyses. The final data set consisted of 26 known road mortality locations: 18 males, 7 females, and 1 unknown sex (Fig. 1.2). I defined my area of interest by generating a 10-km buffer around the aggregated road mortality locations to include a broad area available for ocelots to have used.

I used 30-m LANDSAT satellite imagery that overlapped with the timeframe of known ocelot-vehicle collisions to evaluate spatial structure of land-cover features in the study area. I acquired 15 LANDSAT images taken within 2 years of each collision through the U.S. Geological Survey Global Visualization Viewer (https://glovis.usgs.gov/). Images consisted of 10 LANDSAT 5 Thematic Mapper scenes (1986–2010) and 5 LANDSAT 8 Operational Land Imager scenes (2014–2017; Table 1.1).

I created land-use cover maps using an unsupervised image classification (Xie et al. 2008, Lombardi et al. 2020a) in ERDAS IMAGINE 2018 (Hexagon Geospatial, Norcross, GA). I grouped each image into 4 cover classes: woody vegetation cover, herbaceous vegetation cover (i.e., non-woody), bare ground, and water. To properly address and classify urban areas, I fused layers of digitized urban areas from 1987, 1992, 2000, 2008, and 2016 based on spatial data from the U.S. Census Urban Area from the Texas Natural Resource Information System (TNRIS, Austin, TX). Cropland varied by year and season and often had similar spectral signatures to woody cover, which led to inaccurate images. Therefore, I manually digitized crop fields for each image and fused these layers to my classified imagery in addition to the digitized urban layers. Final imagery included 6 cover classes: woody, herbaceous, bare ground, water, cropland, and urban. I conducted accuracy assessments on each image by generating 200 random points across each satellite image, assigning each random point to 1 of the 6 classes, and compared the observed cover class to the expected cover class from the classified image. I used a threshold of ≥ 85% accuracy for image classifications (Jensen 2016; Pulighe et al. 2016).