RESOURCE SELECTION AND LANDSCAPE CONNECTIVITY OF THE OCELOT (*LEOPARDUS PARDALIS*) IN SOUTHERN TEXAS

A Dissertation

by

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ABSTRACT

Resource Selection and Landscape Connectivity of
the Ocelot (*Leopardus pardalis*) in Southern Texas

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Wildlife species across the globe are faced with landscapes that are becoming increasingly difficult to traverse because of habitat loss and degradation. Roadway networks are widespread and significant anthropogenic influences on the landscape that can have profound impacts on wildlife populations. Understanding how organisms perceive barriers to movement, or landscape resistance, is important for the conservation and management of wildlife populations threatened by habitat fragmentation and loss. The ocelot (*Leopardus pardalis*) is an endangered felid in the United States, with remnant populations in the Lower Rio Grande Valley (LRGV) of southern Texas. An estimated 95% of native Tamaulipan thornshrub had been cleared for agriculture and urban development which has led to the LRGV being classified as one of the most rapidly developing urban areas in the United States today. This development corresponded to an increase in road collisions and a decrease in available habitat for ocelots. To guide efforts to mitigate ocelot road mortalities, I have modeled probability of landscape use by ocelots as a function of environmental resources (e.g., vegetation cover) and road characteristics at the individual and population level. I modeled resource selection from animal location data collected via VHF and GPS radio collars from 1982–2017. I quantified spatio-temporal consistent habitat for ocelots compared to land ownership. I evaluated differences in individual

behavior to habitat and road variables using functional response analyses. I evaluated potential movement pathways between habitat patches and across roads based on landscape resistance scenarios using spatially absorbing Markov chains. This project will inform the placement of future road crossing structures to decrease ocelot-vehicle collisions and increase landscape permeability for this endangered species. This information will assist Texas Department of Transportation with ocelot conservation objectives.

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NOMENCLATURE

AADT	Annual Average Daily Traffic
GPS	Global Positioning System
IQR	Inter Quartile Range
LANWR	Laguna Atascosa National Wildlife Refuge
LRGV	Lower Rio Grande Valley
MCP	Minimum Convex Polygon
RSF	Resource Selection Function
SAMC	Spatially Absorbing Markov Chains
TXDOT	Texas Department of Transportation
VHF	Very High Frequency

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CHAPTER 1: INTRODUCTION

Human mediated change to the landscape has been identified as a major threat to biodiversity. Across the globe, wildlife species face landscapes that are becoming increasingly fragmented and degraded. Efforts to retain landscape connectivity are a conservation priority in response to land development, road networks, and climate change. Many species, especially mammals, require large areas to maintain population connectivity and these species can be particularly sensitive to reductions in landscape connectivity and loss of habitat due to human disturbance. It is therefore critical to understand the impacts human activities have on animal-habitat relationships for the conservation of threatened and endangered species.

Human activity on the landscape can lead to changes in animal movement, survival, and reproductive rates. Landscape connectivity and resource availability have changed drastically for numerous species over the last several decades as human populations continue to expand and agricultural demands increase. Therefore, evaluating trends in habitat and behavioral responses is critical. However, long-term habitat studies are rare, often due to challenges in monitoring. Habitat and species conservation strategies hinge on in depth knowledge of space use by animals with emerging threats to habitat often best understood from broad-scale, long-term monitoring.

Roads are a prime example of increased human activity over the last several decades on the landscape that can lead to drastic changes in animal behavior and population persistence. Roads can have large negative impacts on wildlife populations directly from vehicle collisions or indirectly from barriers to movement and behavioral avoidance. Long-term studies on the impacts of roads on wildlife species can greatly improve conservation efforts and mitigation plans.

Previous research indicates mammals with large spatial requirements, like carnivores, should be considered priorities when mitigating the negative effects of roads on wildlife. Carnivores are particularly susceptible to reductions in connectivity from roads given their large spatial requirements and relatively low reproductive rates. I examined habitat use and landscape connectivity for an endangered species that is directly threatened by habitat loss and vehicle-collisions.

I focused on the ocelot (*Leopardus pardalis*), an endangered felid in the United States (US) with the only known breeding populations isolated to South Texas. Ocelots are hypothesized to be habitat specialists in Texas, selecting for dense woody cover such as native Tamaulipan thornshrub. However, urbanization and agricultural development have led to the loss and fragmentation of remaining habitat in South Texas. Further compounding this issue of habitat loss, ocelots are threatened by high mortality rates from vehicle collisions (35-40% for adults annually). South Texas, particularly the Lower Rio Grande Valley, is one of the fastest growing urban areas in the US. As human populations continue to expand within this area, we will likely see a continued increase in transportation-related problems and a decrease in quality of habitat for the endangered ocelot in the US.

In my second chapter, I evaluated resource selection across South Texas by ocelots across roughly the last 35 years (1982–2017). I assessed spatio-temporal consistency in habitat use and then characterized landownership of high-quality habitat to inform conservation efforts. In my third chapter, I evaluated and compared functional responses of ocelots relative to environmental conditions across multiple decades. Behavioral responses can vary across individuals depending on local conditions and availability (broadly described as functional responses), which can reveal additional mechanisms that contribute to the distribution of ocelots in South Texas. Across these two chapters, I examine habitat use across multiple spatial and temporal scales to gain a full picture of ocelot habitat use over the last several decades.

In my fourth chapter, I applied my knowledge of ocelot habitat use and the concept of landscape resistance to model connectivity for ocelots. Landscape resistance is a measure of how difficult an areas is for an animal to move through. This can be based on physical barriers, such as roads, or behaviorally due to poor habitat. I used these connectivity models to inform wildlife crossing structure placement in order to reduce ocelot-vehicle collisions and increase landscape permeability to ocelot movement.

Wildlife crossing structures can be an effective mitigation technique for the impacts of roads on species. However, high construction costs limit the number of structures that can be implemented. It is therefore important to optimize the placement of these structures. My dissertation aims to improve crossing structure placement based on multi-scale ocelot habitat use and connectivity.

CHAPTER 2: MONITORING HABITAT THROUGH TIME FOR AN ENDANGERED CARNIVORE: THE CASE OF OCELOTS IN SOUTH TEXAS FROM 1982-2017

Abstract

Human-mediated encroachment and fragmentation of habitat is the largest threat to biodiversity worldwide. Understanding the dynamic between habitat change and animal behavior is critical for conservation, yet long-term studies of habitat selection and monitoring are rare. We used a 35-year dataset (1982–2017) to assess resource selection by an endangered carnivore and habitat specialist, the ocelot (*Leopardus pardalis*), in South Texas, United States (US). We used a timeseries of remotely-sensed imagery to map change in availability of woody cover, which is critical to ocelots but has decreased in availability due to anthropogenic development. We fit individual-specific resource selection functions to assess habitat selection for 78 ocelots at the landscape scale (2^{nd} order). Ocelots were grouped based on sex and spatial data collection time frame, and we fit global models to estimate effect sizes across individuals within groups. We used group-level coefficients to map probability of use across our study area. Average availability of woody cover decreased since the 1980s (0.44 in 1985 to 0.39 in 2015, $p < 0.001$), and ocelots used areas with a higher proportion of woody cover (≥0.48) and farther from high-traffic roads (0.14–14.82 km) compared to average availability (4.20 km). Both sexes were predicted to consistently (≥ 3 time periods) use areas with high proportions of woody cover around. Further, areas closer to high-traffic roads were consistently predicted as non-habitat. However, the extent of predicted habitat never exceeded 47% (1,515 km^2) of the study area, illustrating the confined nature of ocelot habitat within its known US distribution.

This chapter follows the style of Ecosphere journal.

We discovered strong, positive correlations (ρ = 1) in predicted ocelot use across time, which indicates increased use across time and ocelots keying in on intact, dense patches of woody cover farther from roads. Private lands consistently contained ≥79% of the predicted high-quality habitat over time. Therefore, the future of ocelots in the US relies on private land stewardship. Managers should pursue landowner incentive programs and conservation agreements to ensure the long-term preservation of quality habitat.

Keywords: habitat use, habitat monitoring, ocelot, private land stewardship, resource selection functions, road ecology, temporal change

Introduction

Human-mediated habitat change has been identified as the main threat to biodiversity worldwide (Vitousek et al. 1997; Tilman et al. 2017). Understanding relationships between wildlife and their habitat is critical for conservation of biodiversity (Cramer and Bissonette 2005) and improved management of natural resources (Morrison 2001). Managers need to understand animal-habitat relationships, particularly for species of conservation concern (Elith and Leathwick 2009; Holbrook et al. 2017), and have a clear definition of habitat for a species of interest (Morrison 2001). Identification of resource selection patterns is critical in efforts to conserve endangered species as it provides fundamental information and can highlight attributes important for survival and reproduction (Manly et al. 2002). Changes in movement, survival, and reproductive success of individuals may result from increased human activity on the landscape (Chen and Koprowski 2016a). As landscapes are altered through time, it is crucial to understand underlying demographic trends in animal populations and resulting changes in behavioral patterns (Anderson et al. 2012; Shoemaker et al. 2018).

Evaluation of temporal changes in habitat, and subsequent behavioral responses by wildlife is particularly important for federally threatened or endangered species. The United States (US) Endangered Species Act requires the designation of 'critical habitat,' and implicitly suggests that monitoring 'critical habitat' over time is essential. Habitat and species conservation strategies hinge on knowledge of space use by animals (Aarts et al. 2008). Highly mobile species further complicate habitat monitoring due to large scale occupancy and use patterns, yet emerging threats to habitat can often only be understood from broad-scale monitoring across space and time (Simons-Legaard et al. 2016).

When planning long-term conservation efforts for animals, researchers often rely on temporally restricted insights generated from short-term research. In contrast, long-term studies and temporal monitoring of habitat can provide crucial information for conservation planning. Remote sensing techniques have been widely used in vegetation mapping and assessments of spatial distributions of wildlife (Xu et al. 2013; Mata et al. 2018). Use of remote sensing approaches provide the ability to monitor vegetation spanning large spatial extents, analyze spatial dynamics, and examine long-term data (Lombardi et al. 2020a). Remotely sensed repositories are increasingly being used to map land cover, monitor temporal trends, and compare between landscapes (Hansen et al. 2013; Savage et al. 2018; Vogeler et al. 2018). Satellite imagery has been widely used in building habitat models for many animal species, including assessments of functional landscape connectivity and designation of critical habitat for recovery (Morzillo et al. 2011; Roever et al. 2013). Despite these applications, long-term studies are often lacking in animal ecology and conservation (e.g., Bartel and Sexton 2009; Simons-Legaard et al. 2016).

The ocelot (*Leopardus pardalis*) is a federally endangered carnivore in the US and occurs in two remnant populations along the US-Mexico border (Janečka et al. 2016). Once ranging across most of the southern US, the ocelot is now restricted to extreme South Texas (Tewes and Everett 1986; Janečka et al. 2016). Ocelots in the US are considered habitat specialists, strongly linked to dense thornshrub communities (Tewes 1986; Shindle and Tewes 1998; Harveson et al. 2004). More specifically, ocelots use dense woody vegetation, particularly native thornshrub, with 95% vertical and >75% horizontal canopy cover, showing avoidance for open land cover types at coarse spatial extents and higher orders of selection (i.e., second and first-order; Johnson 1980; Harveson et al. 2004; Jackson et al. 2005; Horne et al. 2009).

In the US, <80 ocelots exist in two isolated breeding populations in South Texas (Haines et al. 2006; Janečka et al. 2011; Janečka et al. 2016). One population includes ~80% of ocelots in Texas existing on private ranchlands to the north, while the other occurs in and around Laguna Atascosa National Wildlife Refuge (Haines et al. 2005; Tewes 2019). Despite the close proximity (~30 km) between the two populations, significant genetic differentiation was observed (Janečka et al. 2011). Both populations occupy areas that fall within the Lower Rio Grande Valley (the valley). The valley is a rapidly expanding urban area resulting in increased infrastructure (Tiefenbacher 2001), including the expansion and development of transportation networks (Lombardi et al. 2020a). The absence of any detectable gene flow between the populations implies that human modified landscapes of the valley act as a strong barrier to ocelot movement (Janečka et al. 2011). With the growth of human population centers in the valley, ocelots are facing growing pressure to survive in an increasingly fragmented landscape. This pressure is exacerbated by the development of road networks, with vehicle collisions estimated to account for 35–40% of ocelot mortality– the highest source of direct mortality for ocelots in this region (Haines et al. 2005; Blackburn et al. 2021). Expansion of road networks will likely lead to a continued increase in transportation-related ocelot mortality and decrease in accessible habitat (Haines et al. 2005; Blackburn et al. 2021).

Texas is comprised of 96% privately owned land (US Census 1991; NRI 2014). Private lands occupied by ocelots in Texas and to the north of the valley are predicted to have the largest remaining patches of woody cover by 2050 (Lombardi et al. 2020a), indicating private ranchlands will likely act as important refugia for ocelots in South Texas (Tewes 2019). However, habitat monitoring can be challenging, particularly on private lands due to stakeholders' willingness and capacity to participate (Knight et al. 2010; Raymond and Brown