OCELOT (*LEOPARDUS PARDALIS*) SURVIVAL AND TOXICITY-RELATED THREATS TO SURVIVAL IN SOUTH TEXAS, USA

A Thesis

by

VICTORIA L. LOCKE

Submitted to the College of Graduate Studies
Texas A&M University-Kingsville
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2025

Major Subject: Range and Wildlife Management

OCELOT (*LEOPARDUS PARDALIS*) SURVIVAL AND TOXICITY-RELATED THREATS TO SURVIVAL IN SOUTH TEXAS, USA

A Thesis

by

VICTORIA LOCKE

Approved as to style and content by:

Lisanne Petracca, Ph.D.
Committee Chair

Evan Tanner, Ph.D.
Committee Member

Ashley Reeves, Ph.D.
Committee Member

Julie Young, Ph.D.
Committee Member

Clayton Hilton, D.V.M.
Committee Member

Bart Ballard, Ph.D.
Department Chair

Darin T. Hoskisson, Ph.D.
Associate Vice President for Academic Affairs
and Dean, College of Graduate Studies

December 2025

ABSTRACT

Ocelot (*Leopardus pardalis*) Survival and Toxicity-Related Threats to Survival in South Texas, USA

December 2025

Victoria Locke, B.S. Forestry and Wildlife Management

The Ohio State University

Chair of Advisory Committee: Dr. Lisanne Petracca

Estimation of population parameters is essential to understand the complexities of population dynamics and inform population management. Survival is one of the most well-studied population parameters, commonly estimated for adults and less so for juveniles and neonates. Survival of young is particularly difficult to estimate in cryptic, low-density species. Knowledge of both adult and young survival is important in any stage-based forward simulation of population growth, where these parameters can be used in a population viability analysis (PVA) to determine outcomes such as the probability of extinction of a population. Population viability is of particular interest for small, declining populations, such as the ocelot (*Leopardus pardalis*) in the United States. There may be as few as 100 ocelots in the United States within two breeding populations in South Texas (the Ranch centered at El Sauz Ranch and the Refuge in Laguna Atascosa National Wildlife Refuge), making this species of great conservation interest. The ocelot breeding populations overlap with two similarly sized, abundant mesocarnivores: bobcats (*Lynx rufus*) and coyotes (*Canis latrans*). I had three research aims: (1) estimate sex-specific six-month apparent survival of ocelots over one year old in both extant breeding populations in the United States; (2) use population projections to estimate sensitivity of abundance and population growth to variation in ocelot kitten survival; and (3) determine exposure of ocelots, bobcats, and coyotes to toxicity-related threats to survival, namely anticoagulant rodenticides and lead, the former of which had never been investigated in this system. First, I estimated six-month apparent survival of ocelots using a Cormack-Jolly-Seber (CJS) model in a Bayesian framework. I identified 37 unique ocelots across both populations (19 in Ranch, 18 in Refuge). Apparent six-month survival for males was 0.95 (95% Bayesian Credible Interval [BCI] 0.90 – 0.98) in the Ranch population and 0.97 (0.92 – 0.99) in the Refuge population, while female apparent six-month survival was 0.94 (0.93 – 0.99) in the Ranch population and 0.97 (0.85 – 0.99) in the Refuge population. In support of my second aim, I found that variation in six-month kitten survival (using values from 0.0 to 1.0 in increments of 0.2) was a strong driver of five-year simulated population projections. Population growth (λ) ranged from 0.92 to 1.18 across values of kitten survival, and declined (i.e., was <1) when six-month kitten survival was <15% in the Ranch and <29% in the Refuge. Third, in testing ocelot, bobcat, and coyote exposure to anticoagulant rodenticides (ARs) and lead, I detected ARs in 8 of 39 (20.5%) of all tested liver samples, and 3 of 5 (60%) of ocelot liver samples contained at least two AR compounds. One liver from an ocelot male had a level of an AR 4x that of a toxicosis-related death in a bobcat reported in another system. These findings represent the first detections of ARs in South Texas and the first detection in the federally endangered ocelot. I detected lead in 7 of 27 (25.9%) of liver samples and 5 of 102 (4.9%) of whole blood samples, with all lead values under reported toxicosis limits for mammals. I suggest further monitoring to determine what threat ARs pose to ocelots in South Texas. Overall, my work underscores the importance of estimation of survival of young in small, declining populations, as well as the potential for lethal and sublethal effects of toxicity-related substances in the environment on endangered wildlife.

DEDICATION

I dedicate this thesis to those who supported me in this endeavor: my mother, for nurturing my curious nature; my husband, for his unconditional love and patience; and my cat, Tango, who was my constant companion as I wrote this thesis.

ACKNOWLEDGEMENTS

I thank my committee chair, Dr. Petracca, for her support and guidance on this journey. You kept me grounded when I had approximately one million ideas and you helped turn my research interests into reality.

I thank my committee members, Drs. Tanner, Reeves, Young, and Hilton for lending their expertise and knowledge to my project. I appreciate the time you committed to this project and the advice you gave along the way.

I would also like to thank all of the collaborators on this project. This project was made possible with support from the United States Fish and Wildlife Service, Laguna Atascosa National Wildlife Refuge, the East Foundation, Dr. Tewes' Lab, the LEADING Program, and various private landowners. The collaboration with these groups was integral for sample acquisition, land access, funding, and use of historic data. A special thanks to the undergraduate workers for sorting a large portion of the photo data and the technicians who collected that data.

Lastly, I thank my lab mates in the Spatial Population Ecology of Carnivores (SPEC) Lab for their unwavering support and friendship. Specifically, I thank Alexandria, Tyler, and James for their sense of humor, long phone calls, and so many mental health walks.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Drs. Lisanne Petracca, Evan Tanner, and Clay Hilton of the Department of Range and Wildlife Sciences, Texas A&M University – Kingsville, Dr. Ashley Reeves of the East Foundation, and Dr. Julie Young of Utah State University's Department of Wildland Resources.

Samples analyzed for this thesis were collected in partnership with the Caesar Kleberg Wildlife Research Institute, East Foundation, and private landowners. Blood and tissue sample analysis was conducted by the Texas A&M Veterinary Medical Diagnostic Laboratory.

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

Funding Sources

Graduate study and research were supported by Customs and Border Protection through the United States Fish and Wildlife Service under Contract Number 140F0S23C0008. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of Customs and Border Protection or the United States Fish and Wildlife Service. The LEADING program at Texas A&M University – Kingsville covered the cost of lead sample processing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

CHAPTER I: ESTIMATION OF ADULT SURVIVAL AND POPULATION SENSITIVITY TO KITTEN SURVIVAL IN AN ENDANGERED FELID

INTRODUCTION

Efficient estimation of population parameters is essential for projecting population dynamics and managing small, declining populations. An increase in human disturbance has resulted in increased species extinction rates, with the Anthropocene characterized by ~1000x the background rate of extinction (Pimm et al., 2014). Even well-studied species are experiencing shrinking ranges (Wolf and Ripple, 2017), and species extinctions are projected to increase due to factors ultimately driven by human population growth and resource consumption (Pimm et al., 2014). Therefore, it is especially important to estimate vital rates (e.g., survival, reproduction) for populations of conservation concern to assess population viability and assist future recovery efforts (Morris and Doak, 2002). Population-level declines across taxa have been linked to lower survival of adults as well as young (DePerno et al., 2000, Buehler et al., 2008, Griffiths et al., 2010), underscoring the importance of understanding survival in wildlife populations.

Survival is an important population parameter that is associated with increased reproductive output (Hutchings, 1993, Schmutz et al., 1997), intra- and interspecific interactions (Persson et al., 2003, Liesenjohann et al., 2011), and population growth (Benson et al., 2016, Nisi et al., 2023). Species with differing life histories generally have divergent emphases on age-structured survival to drive population growth. For example, species that produce young frequently and have relatively short lifespans may be more dependent on the survival of offspring (e.g., rodents and rabbits; Heppell et al., 2000), as opposed to species that produce young less frequently and have longer lifespans, which may be more dependent on adult or juvenile survival (e.g., black bear and monk seals; Kerk et al., 2013).

Adult survival is a commonly estimated survival parameter, while juvenile and neonate survival are often lacking to form a complete picture of population demographics and associated population growth (Eberhardt, 1985, Heppell et al., 2000). Survival of young has been estimated for avifauna through the use of leg bands (Seber, 1972), and more recently for ungulates with the use of light, expandable collars (Dion et al., 2020). Each species poses a unique set of challenges to estimating survival of young. This is true for smaller carnivores ≤ 10 kilograms, which, like young avifauna, are small and cryptic. With recent technological advances, lightweight, expandable collars have become a viable option to use in estimating early survival for carnivores. Survival of young has now been estimated for cougar (*Puma concolor*, Engebretsen et al., 2023) and bobcat (Morrison, 2022) kittens, thereby elucidating survival at a life stage that was previously unknown.

While it is important to gain an understanding of age-structured survival estimates given a species' life history strategy, it is also of management concern to capture uncertainty of survival estimates (McGowan et al., 2011). For example, the outcome of a population viability analysis (PVA), a quantitative tool to estimate the future trends of a population (Morris et al., 1999), can vary greatly depending on not just the survival parameters, but also the variance associated with those parameters (Cross and Beissinger, 2001). PVAs usually incorporate age-structured models of population growth, such as a Leslie matrix, to account for demographic processes within a population (Boyce, 1992) and can guide managers in knowing whether it is more important to ensure, for instance, adult survival over the survival of young (Crouse et al., 1987). Factors affecting population persistence can vary, and some populations may be more sensitive to first-year (*Ciconia boyciana*, Sung et al., 2012) or adult (*Ara glaucogularis,* Bouzat and Strem, 2012) survival rates.

Survival estimates are commonly the result of long-term studies of marked (or uniquely identifiable) individuals within a mark-recapture framework (Buckland, 1982). These marks can either be applied by humans (e.g., ear tags) or occur naturally (e.g., scars, coat patterns). By using remote camera traps, researchers can use natural marks to identify individuals and estimate the demographics of a population without physically capturing individuals. Due to their unique pelage patterns, it is common for felid species to be the subject of mark-recapture studies (Karanth, 1995; Trolle and Kéry, 2003; Silver et al., 2004; Jackson et al., 2006; Marnewick et al., 2008; Mondal et al., 2012; Lombardi et al., 2022; Sternberg et al., 2023), though these analyses tend to focus on adult survival.

My work focuses on better understanding (1) six-month, sex-specific apparent survival and (2) sensitivity of population growth to kitten survival within the only two breeding populations of ocelots (*Leopardus pardalis*) in the United States. Previous research in the study system estimated annual adult survival for resident ocelots ($\hat{S}$ =0.87, SE 0.05; Haines et al., 2005) and kittens to one year old ($\hat{S}$ = 0.68; Laack et al., 2005). These results are now over 20 years old, and increased human development in the study area (Blackburn et al., 2021*b*) is likely affecting survival. In addition, technological advancements are expected to improve survival estimation. Importantly, the first-year kitten survival estimate assumed that kittens older than six months had the same survival probability as resident adults, which may be untrue due to vulnerability of young to predation or starvation (Morrison, 2022). I expected that females would be detected less overall due to their smaller home range size (Smith et al., 2025), but that survival estimates would be similar between sexes, as reported by previous research in South

Texas (Haines et al., 2005, Blackburn et al., 2021*b*). I also expected adult survival to be high due to the lack of predation or human harvest of ocelots in this system. Lastly, I expected population abundance and growth to be impacted by reduced kitten survival, and that lower kitten survival estimates would lead to a decreasing or a more slowly growing population. This is because ocelot litter size is small (one or two kittens per litter [Laack 1991], compared to two to five kittens per litter in bobcats and two to six per litter in mountain lions [Winegarner and Winegarner, 1982; Riley et al., 2014]) and females invest at least one year into rearing their young (Laack, 1991), making the survival of young compared to other wild felids important for continued population growth.

Ultimately, the contracted geographic range of ocelots, coupled with signs of genetic inbreeding (Bostwick, 2025), make a better understanding of population parameters essential for ocelot management and recovery decisions. More broadly, my work underscores the importance of estimating survival beyond that of adults to properly capture population dynamics, with this work particularly pressing for endangered species in cases where these parameters are either poorly estimated or unknown.

METHODS

Study area

The study sites are within the Tamaulipan Biotic Province, which ranges from South Texas into northern Mexico (TPWD, 2000). This region is dominated by thorny brush, including various *Acacia*, *Condalia*, *Castela,* and *Mimosa* species as well as mesquite (*Neltuma glandulosa*), Texas ebony (*Ebenopsis ebano*), and granjeno (*Celtis pallida*; Jahrsdoerfer and Leslie, 1988). The region supports a diverse array of grasslands, forests, and coastal marshes, as well as agricultural fields, which are prevalent throughout (TPWD, 2000). This varied landcover provides habitat for mesocarnivores in addition to ocelots, such as bobcats, coyotes, gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), opossum (*Didelphus virginiana*), and striped skunks (*Mephitis mephitis*; Schmidly and Bradley, 2016). The climate is semi-arid and subtropical (Jahrsdoerfer and Leslie, 1988), with an average annual rainfall of 50.8 to 81.28 centimeters. The majority of monthly rainfall occurs in spring (May, June) and fall (September), and is lowest during the winter months (generally considered December through February; TPWD, 2025). While density estimation is not yet complete, there are believed to be as few as 100 individuals across these two populations, and Tamaulipan thornscrub, which ocelots are associated with in the system, has been reduced by an estimated 95% from the early 1900s to the late 1980s (Jahrsdoerfer and Leslie, 1988). This reduction in Tamaulipan thornscrub is due to clearing vegetation for agriculture and urban development (Jahrsdoerfer and Leslie, 1988). From 1987 to 2016, urban development has quadrupled along the South Texas-Mexico border and is expected to continue to increase (33.4% - 39.2%; Lombardi et al., 2020). This increase, combined with the fact that thornscrub restoration is hampered by stressors (herbivory, extreme heat, competition with invasive grasses; Vela, 2015) presents a challenge in regard to the restoration of large habitat patches suitable for ocelots.

This study took place within the only known breeding populations of ocelots in the United States: one at El Sauz Ranch ("Ranch"; 109.84 km^2), managed by the East Foundation, and the other at a portion of Laguna Atascosa National Wildlife Refuge ("Refuge"; 357.70 km^2), managed by the United States Fish and Wildlife Service (USFWS) (Figure 1.1). El Sauz is historically a cattle ranch, and the East Foundation continues ranching operations while integrating conservation practices and wildlife management. The Refuge was established in 1946 to protect habitat for waterfowl and migratory birds and is managed for wildlife viewing and recreation. While these properties are approximately 20 kilometers apart, both populations face genetic issues caused by inbreeding (Bostwick, 2025).

Camera grid

I used an established camera grid at each ocelot breeding population (Ranch, Refuge), for a total of 233 camera stations (110 at the Ranch, 123 at the Refuge) spaced approximately 1 km apart. Cameras were active from 2024-02-09 to 2024-08-08 at the Ranch and from 2024-05-22 to 2024-11-20 at the Refuge. These dates reflect the installation of each respective site's camera grid, which began at the Ranch and concluded at the Refuge, with about three months of temporal overlap. Each camera station had two RECONYX brand HyperFire 4K Professional series cameras positioned on opposing sides of a game trail, for a total of 466 cameras across both sites (220 at the Ranch, Figure 1.2; 246 at the Refuge, Figure 1.3). Each camera was attached to metal T-posts hammered into the ground and located ~1.5 ft from ground level. Positioning the cameras on either side of the game trail allowed us to capture identifiable pelage patterns on both sides of an individual at the same time, confirming individual identity (Karanth 1995). Cameras were visited approximately every two months to clear vegetation at the site, change batteries, and replace SD cards.

In total, the 466 cameras were active across 58,555 trap-nights. This was the cumulative result of 220 cameras active at the Ranch population for a total of 27,651 trap-nights, and 246 cameras active at the Refuge population for a total of 30,904 trap-nights. I identified ocelots from photos using a combination of manual tagging in Program Timelapse v.2 (Greenberg et al., 2019) and artificial intelligence (Megadetector v5; Beery et al., 2021 and speciesnet v5; Gadot et al., 2024), and then identified to individual level using observations of distinct markings. It is