Urban Development Pressure and the Florida Panther

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Introduction

The Florida panther is one of the most endangered mammals in North America. This species faces immense pressure from urbanization, including habitat fragmentation, habitat size reduction, and even death through vehicular collisions. As humans continue to encroach upon the Florida panther's core habitat in Southwest Florida, the conflict between human development and wildlife conservation becomes increasingly apparent. Vehicle collisions are a leading cause of panther mortality, and this trend is only getting worse due to the expanding road networks and traffic volumes associated with population growth.

This research project will investigate how patterns of human development relate to vehicular-related panther deaths over time. Census tract variables from 2010 to 2020, such as population density, median home value, and mean travel time to work, will be evaluated to determine if these variables of development can predict mortality hotspots. Examining this census data at the tract level also allows for a targeted comparison between demographic data and documented collision deaths. The overall goal of this project is to understand how human development patterns align with vehicular related mortality and how this understanding can help guide future conservation efforts, inform policy decisions, and support strategies to mitigate future panthers and other animal deaths from collisions.

Literature Review

There has been a range of research based around wildlife-vehicle collisions ranging from studies that identify spatial hotspots to determine which roads fragment habitats the most. Several researchers have shown that collisions are strongly influenced by how people develop the landscape. For instance, Litvaitis & Tash (2008) found that road density, habitat layout, and human activity all can affect where wildlife deaths happen. They combined spatial data with human developmental variables like traffic volume or number of lanes to identify high risk areas, which is similar to the census tract approach used in this paper. Additionally, a study done by Morelle et al. (2013) found that collisions tend to cluster in places with busy roads and expanding developmental patterns.

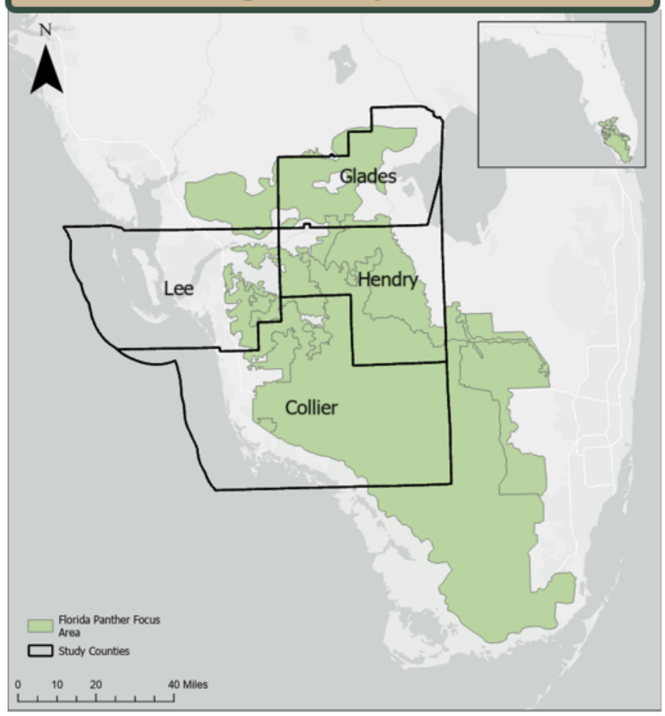
There are a few instances of research focused specifically on the Florida panther. McClintock et al. (2015) found that vehicle related panther mortality is tied to human expansion, and their findings were so significant that these deaths can be used to understand panther population trends as a whole. His study also used panther motor vehicle mortality points for spatial analysis. A similar study done by Cramer & Portier (2001) used movement modeling to analyze how panthers navigated fragmented habitats. They found that variables such as human density and changes in land use can influence where a panther will travel and where they face increased risk.

Other studies use different geospatial methods for a similar analysis. For instance, Ha and Shilling (2017), used Maxent to predict wildlife collision hotspots by combining both environmental and human related variables. Ng et al. (2008) also did a hotspot analysis where variables like proportion of forested land, speed limit, traffic volume, and distance to body of water were all used as different predictor variables for the hotspots. Additionally, Clark (2003) highlights that human population density was inversely related to traffic mortality, suggesting that rural areas often pose higher lethality risks due to higher speeds and distance from medical care. This supports the idea of using the transition from urban to rural zones as a critical zone for analysis. Both of these studies show that using a combination of demographic data, as well as factoring in traffic information, can be used for predicting where collisions occur. Overall, this previous research demonstrated that GIS techniques and census tract demographic data can be used in order to better understand how the development patterns in Southwest Florida are possibly contributing to panther mortality.

Data

This project uses a combination of data sources ranging from panther mortality data and boundary files to demographic datasets to analyze how patterns of human development relate to Florida panther deaths caused by vehicles. The primary dataset is the Florida Panther Mortality Database layer obtained from the Florida Fish and Wildlife Conservation Commission's (FWC) open GIS data portal. The layer provides locations for all recorded panther deaths and includes an attribute table displaying additional information about each death. Only mortalities that are classified as a result of vehicle collisions will be used in this study. This dataset spans from 1972 to 2024, but this project will focus on deaths that occurred between 2010 and 2020 in order to match the census data timeframes.

Figure 1: Study Area



To define the study area, this project uses the Florida Panther Focus Area boundary which is provided by the U.S. Fish and Wildlife Service. This polygon outlines the region where panther conservation efforts are concentrated and covers much of Southwest Florida. This study area overlaps with four main counties: Glades County, Hendry County, Collier County, and Lee County. The study area can be observed below in Figure 1. The mortality data was clipped to only include death points located within these four counties.

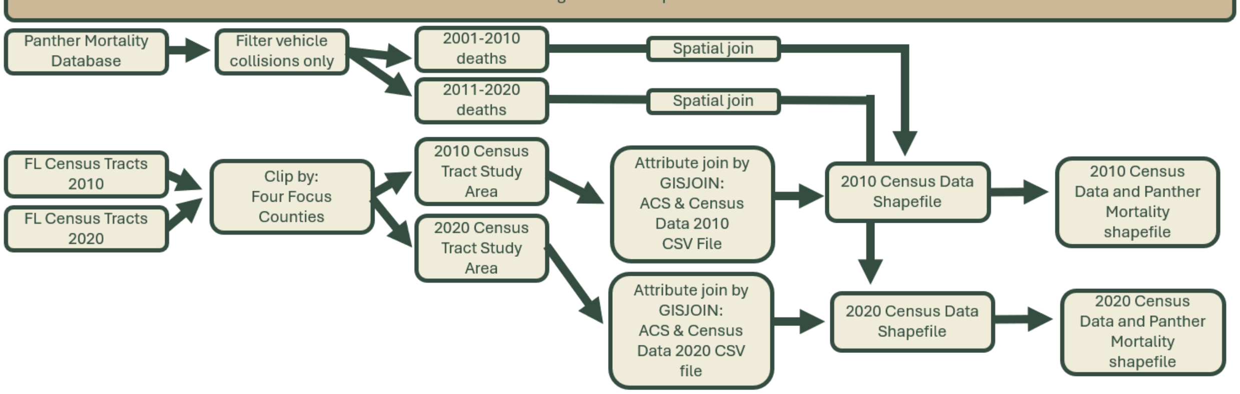
The human demographic and economic data were sourced from two primary providers. First, American Community Survey (ACS) 5-Year Estimates were obtained via IPUMS NHGIS. Specifically, variables for Mean Travel Time to Work and Median Home Value were downloaded for the 2010 and 2020 periods. Second, population information was sourced directly from the U.S. Census Bureau, specifically: Total Population and Population living in urban areas. All human data sets were downloaded for both 2010 and 2020 to allow the change over time to be measured. Census tracts are used as the spatial unit of analysis because they provide a relatively stable boundary across time periods. One potential limitation noted is that the ACS data is based on estimates, which can produce wider margins of error in tracts with low populations.

Methods

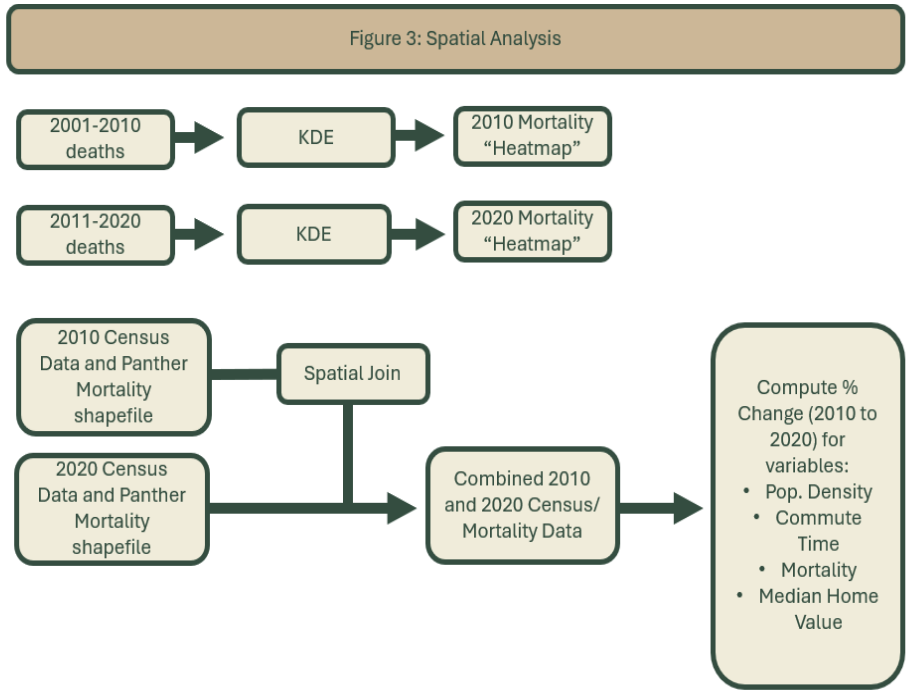
All geospatial processing, data management, and statistical analysis were conducted using ArcGIS Pro. The methodological workflow was designed to combine different dataset types, specifically the point-based mortality data and the polygon-based census data, to allow for a comparison between 2010 and 2020. The analysis proceeded in three distinct phases: data inputs and preprocessing, spatial aggregation, and spatial pattern analysis.

The data inputs and preprocessing phase involved preparing the biological and demographic datasets for consistency in analysis. This workflow is illustrated in Figure 2. The Florida Panther Mortality Database was first filtered using a definition query to isolate only records where the cause of death was classified as a vehicle collision. This filtered dataset was then split into two subsets: 2001 to 2010 and 2011 to 2020. Then the 2010 and 2020 Census tract shapefiles were clipped to the study area boundary, defined by the four target counties: Glades, Hendry, Collier, and Lee. The demographic CSV tables containing the ACS and Census variables (such as commute times and urban population) were cleaned and joined to census tract shapefiles using the "GISJOIN" field as matching attribute. This resulted in two main polygon layers: one for 2010 census data and one for 2020 census data. Finally, the mortality points were spatially joined to these census tracts to create a count of fatal collisions per tract for each decade.

Figure 2: Data Inputs



Two methods were used to interpret the spatial trends, as detailed in the Figure 3 workflow.



First, a Kernel Density Estimation (KDE) was performed on the mortality point subsets (2001 to 2010 and 2011 to 2020) to visualize clusters of accidents independent of arbitrary census boundaries. The KDE tool generated continuous raster surfaces, or "heatmaps," representing the density of deaths per square mile for each period. These heatmaps were crucial for visualizing the directional shift of hotspots over the decade.

Second, a Bivariate Choropleth Mapping technique was employed. The 2010 and 2020 census and mortality shapefiles were combined to calculate the temporal shift in variables. New fields were added to the attribute table to compute the percent change for Population Density, Commute Time, Mortality, and Median Home Value using the standard formula: ((2020 Value - 2010 Value) / 2010 Value) * 100. This calculation allowed the study to generate bivariate maps highlighting "dark zones," which are tracts where development pressure (such as rising commute times) and mortality risk increased simultaneously.

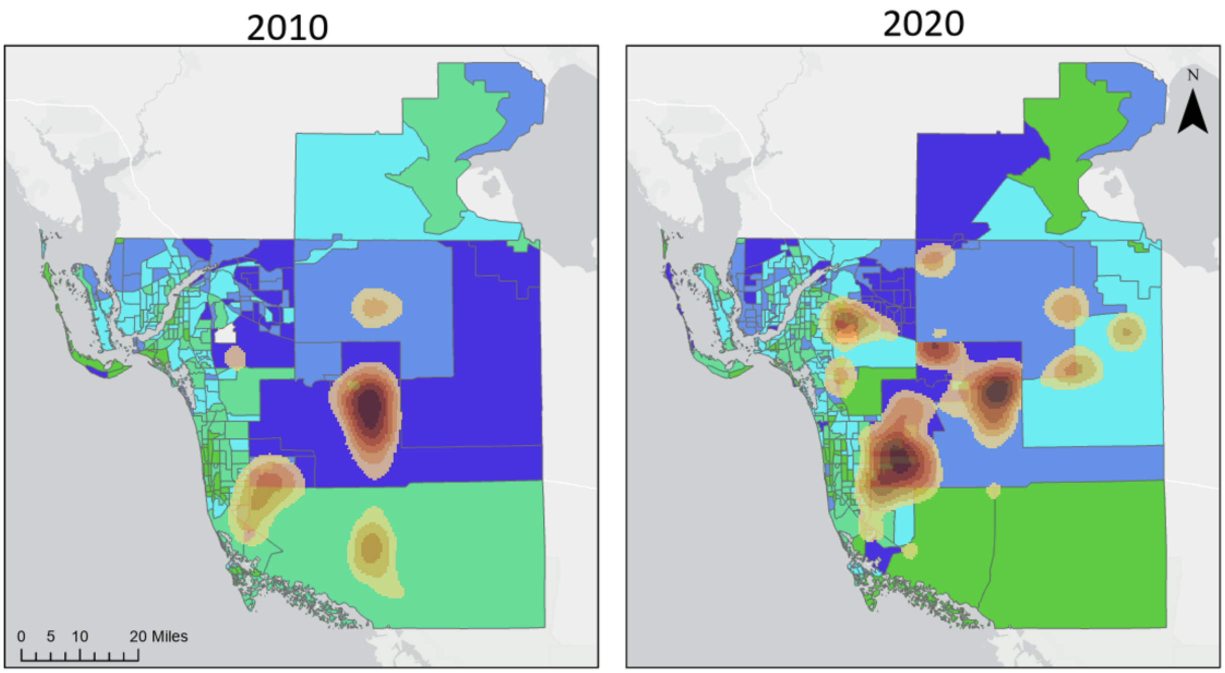
Results

Temporal Shifts in Mortality Hotspots (2010 to 2020)

To address the research question regarding temporal shifts, a Kernel Density Estimation (KDE) was performed for the two decades. The resulting heatmaps (Figure 4) reveal a clear geographic migration of collision risks. In the 2010 analysis, high-density collision zones were discrete and tightly clustered along established major road corridors in central Collier and Lee Counties. These hotspots corresponded with areas of intermediate development where road networks bisect core panther habitats.

Figure 4

Temporal Analysis of Mean Travel Time and Panther Mortality Hotspots



Mean Travel Time to Work

- Less than 20 mins
- 20 to 25 mins.
- 25 to 30 mins.
- 30 to 35 mins.
- Greater than 35 mins.

Mean travel time to work by census tract for 2010 and 2020, overlaid with kernel density hotspots of vehicle-related panther mortalities. In both years, deaths cluster along major road corridors in Collier and Lee Counties, with hotspots expanding eastward and slightly northward by 2020. This shift suggests that growing development and commuter activity are increasing collision risk across a broader area, including tracts extending toward the Fort Myers/ Cape Coral region.

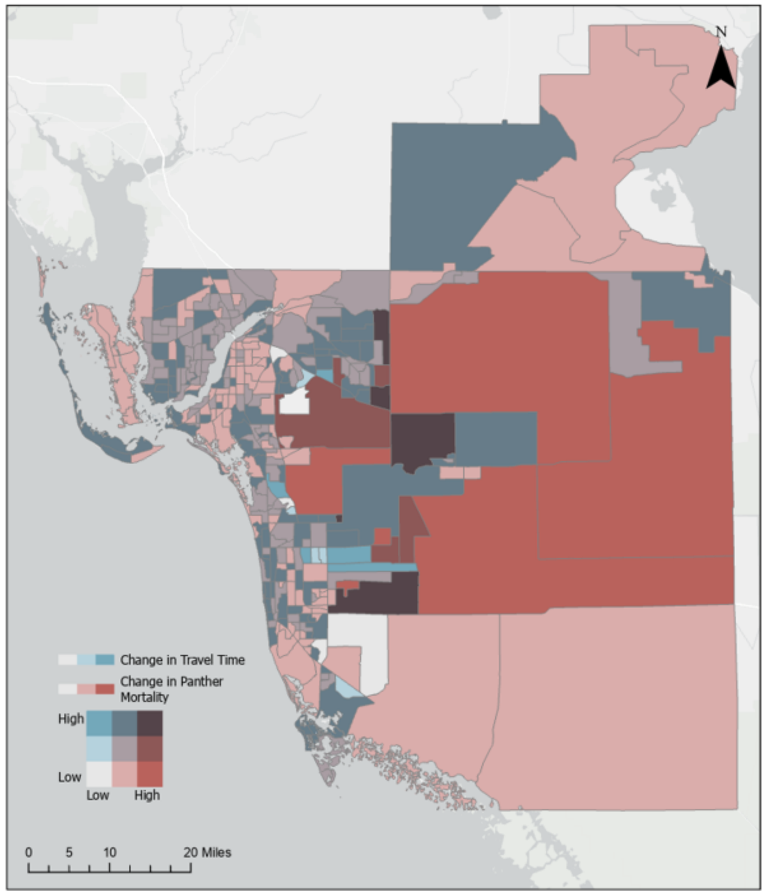
However, the 2020 KDE analysis demonstrates a significant dispersion and migration of these hotspots. Rather than remaining static, the zones of intense mortality expanded notably eastward and northward. This spatial shift correlates with the regional expansion of exurban development. As human communities encroach further into the rural interior, the edge effect, or the area where traffic noise and collision risk impact wildlife has widened. This finding supports the hypothesis that as development sprawls away from the urban core, it drags the conflict zone with it. This outcome aligns with findings by Cramer and Portier (2001), who predicted that increased human density would constrict the panther's home ranges and force movements into less optimal habitats, thereby increasing roadway interactions.

The Correlation Between Commute Times and Mortality

To evaluate impacts of commuter traffic patterns, a Bivariate Choropleth Map was generated comparing the Percent Change in Mean Travel Time to Work against the Percent Change in Panther Mortality (Figure 5). This visualization brings forth the census tracts where both variables are accelerating simultaneously.

Figure 5

Bivariate Map of Percent Change in Mean Commute Time and Panther Mortality (2010–2020)



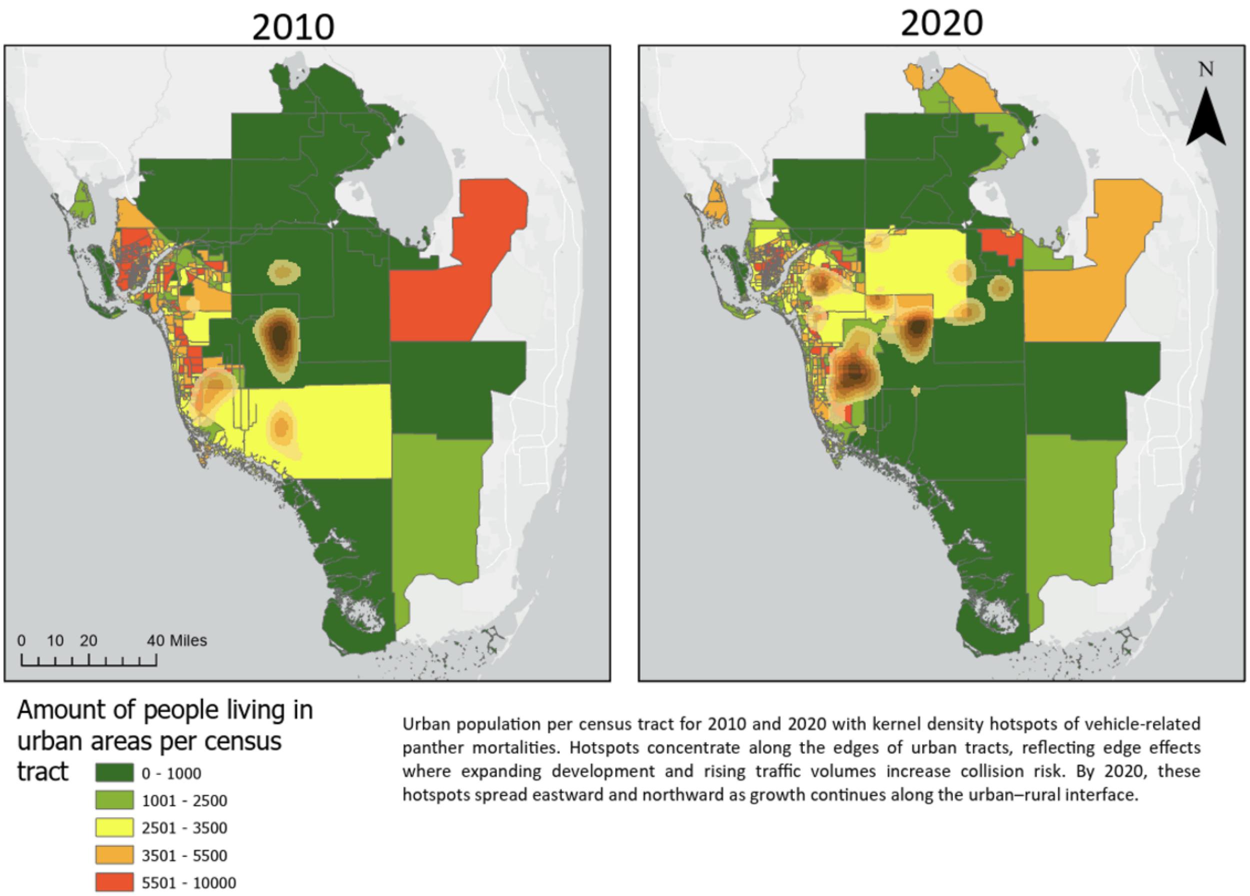
This analysis identified several dark zones. These are tracts colored in the darkest purple hues and are primarily located in the inland, transitional areas of the study region. In these tracts, a sharp increase in average commute time was statistically paired with a sharp increase in panther vehicle collisions. This spatial overlap suggests that commute times does serve as a functional representation for traffic volume and road usage intensity. McClintock et al. (2015) wrote that traffic volume and road density are primary determinants of panther mortality risk. The bivariate results show that rural lands could be experiencing a conversion into bedroom communities, which are residential areas where people live but do not work. These are often associated with long commutes, and the increase in daily vehicular movement creates an ecological trap for panthers. Litvaitis and Tash (2008) wrote that traffic volume is often the most influential parameter in collision models. Their conclusion is supported here by the fact that tracts with stable or decreasing commute times appear to experience fewer increases in mortality.

The Urban-Rural Interface and the Edge Effect

The final analysis overlaid the KDE mortality hotspots onto 2010 and 2020 Census Urban Population data to define the landscape characteristics of high-risk zones (Figure 6). The results reveal an edge effect. Contrary to the expectation that mortality might be highest where human population is densest, the analysis shows that panther collisions are nearly nonexistent in the dense urban cores of Fort Myers and Naples.

Figure 6

Urban Population Distribution and Panther Mortality Hotspots



Urban population per census tract for 2010 and 2020 with kernel density hotspots of vehicle-related panther mortalities. Hotspots concentrate along the edges of urban tracts, reflecting edge effects where expanding development and rising traffic volumes increase collision risk. By 2020, these hotspots spread eastward and northward as growth continues along the urban–rural interface.

Instead, the most intense clustering of mortality occurs consistently along the urban-rural edge, which is the transitional boundary where low-density residential development meets fragmented habitat. This pattern is consistent with Clark (2003), who found that traffic mortality is often inversely related to population density, with higher fatality rates occurring in less dense areas where vehicle speeds are typically higher. The tracts between suburban sprawl and wildlands represent the highest lethality risk, likely due to the combination of high-speed roads required for the long commutes identified in Figure 5 and the remnants of attractive habitat that draw panthers near roadways.

Summary

Collectively, these results answer the primary research questions affirmatively. Panther mortality is not randomly distributed, but rather it is structurally determined by the leading edge of human development. The risk is migrating eastward and northward, driven by the expansion of commuter zones. These findings validate the use of census variables, specifically commute time and urban boundary delineation, as effective predictors for high-risk conservation zones.

Conclusion

This study demonstrates that vehicular panther mortality in Southwest Florida is strongly shaped by expanding patterns of human development. By comparing 2010 and 2020 census variables with spatial analyses of collision points, the results show that mortality is not randomly distributed but instead follows the outward movement of commuter zones and low-density residential growth. Kernel Density Estimation revealed that most of the hotspots have shifted eastward and northward over the decade, which reflects the geographic push of suburban expansion. The bivariate analysis showed that tracts with the largest increases in commute time, which can correlate to rising traffic volume and road usage intensity, also experienced the greatest increases in mortality. Urban population mapping confirmed that the most lethal areas occur not in dense urban cores but consistently along the urban rural edge where habitat fragmentation, high-speed travel, and increased road exposure converge.

Together, these findings display the importance of incorporating human population geographic variables into wildlife conservation planning. However, limitations such as ACS margins of error and the lack of use of detailed traffic volume data reduce the precision of the results. Future research should use materials like traffic datasets or dynamic habitat models for predictive risk mapping. Even with these limitations, this study provides a practical framework for identifying emerging risk zones and shows how human developmental patterns can be used to anticipate and mitigate future panther deaths.

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