Network Analysis of Florida Panther Vehicular Related Mortality

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Introduction

The Florida panther is one of the most endangered mammals in North America. This cat has historically struggled to maintain its population due to habitat loss and fragmentation (McClintock et al., 2015). While conservation efforts have stabilized the population to some degree, the panther population still faces pressure with its recovery. Among the common threats, vehicular collisions have emerged as a primary cause of mortality, often surpassing natural causes such as disease or intraspecific aggression (Taylor et al., 2002). Rapid urbanization, particularly in South Florida, has led to an expansion of road networks that fragment panther habitat while increasing traffic volumes. This infrastructural expansion creates a deadly interaction between wildlife and human development. While traditional GIS methods, such as kernel density estimation, are useful for identifying hotspots of mortality, they often lack details to reveal the underlying structural relationships between the biological attributes of the panther (such as age and sex) and the characteristics of the roadway (speed limit and road class). To address this gap, this project utilizes network analysis to uncover hidden patterns within mortality data. By treating collision events as nodes in a network, one can analyze the complex dependencies between biological susceptibility and infrastructural risk. The goal of this project is to conduct a spatial, temporal, and attribute-based network analysis of Florida panther vehicular mortality from 1972 to 2024.

Background

The Florida panther is restricted to a breeding range of less than 12,600 km² in South Florida (McClintock et al., 2015). Much of the existing literature on panther conservation has focused on habitat suitability and the genetic consequences of population isolation. However, as the human population in Florida grows, the road network has become a dominant feature of the landscape, acting as both a barrier to movement and a direct source of mortality (Blackburn et al., 2021). Vehicular collisions consistently appear as a leading cause of death. Studies have shown that vehicle collisions account for about 30 to 40 percent of known panther mortalities, making road networks a significant influence on population (Taylor et al., 2002). However, collision risk is not distributed evenly across the population. Previous research indicates significant demographic differences in mortality risk. Adult males experience higher rates of vehicle-related mortality, likely due to their larger home ranges and dispersal behaviors that require them to cross major highways more frequently (Taylor et al., 2002). On the other hand, female panthers tend to exhibit road avoidance behaviors, particularly regarding high-speed roadways like Interstate 75, resulting in lower collision rates compared to males (Schwab & Zandbergen, 2011). The type of roadway also plays a critical role. While major highways pose a barrier effect, intermediate roads often result in higher mortality because panthers attempt to cross them more frequently than wider, high-traffic interstates (Blackburn et al., 2021). Continued development in Southwest Florida will likely intensify these pressures, raising the likelihood of future collisions (Blackburn et al., 2021). This requires analytical approaches that go beyond simple counts to examine the structural relationships between panthers and road systems.

Methods

Data Acquisition and Processing

Florida panther mortality records were obtained from the Florida Fish & Wildlife Conservation Commission (FWC). The dataset includes confirmed panther deaths between 1972 and 2024. Key attributes for each event included the date of death, coordinates (latitude/longitude), cause of death, sex, and age class.

The data was cleaned to filter only for vehicular-related mortalities. For a complete network analysis, several attributes were reclassified or added. Panther age was categorized into three classes: kitten, subadult, and adult. The date of death was reclassified into mating season (October through March) versus non-mating season to test for temporal clustering. Finally, roadway attributes were spatially joined to the mortality points, including road names, road class (Federal, State, County, Local), and speed limits.

Network Analysis

Three distinct network analyses were conducted to reveal structural patterns in the data. First, a Temporal Bipartite Network was created. In this graph, one set of nodes represents individual panther deaths, and the other set represents the specific roads where the deaths occurred. This structure allows for the visualization of which roads are hubs for mortality and how these events are distributed over time. Second, Biological Similarity Networks were constructed. In these networks, nodes represent individual mortality events. Edges (connections) were drawn between nodes if they shared specific attributes. One network focuses purely on biological similarities (sharing sex or age class), while a second network integrates collision attributes (sharing speed limit zones or road types). Finally, Community Detection was applied using the Modularity algorithm in Gephi. This technique identifies clusters of nodes that are more densely connected to each other than to the rest of the network. By calculating the modularity score, the algorithm partitions the mortality events into distinct communities. This allows the user to statistically determine if deaths are random or if they naturally cluster based on shared characteristics, such as a specific demographic dying on a specific type of road.

Results

The network analyses revealed that panther vehicular mortality is not random but structured by biological and infrastructural factors.

Temporal and Road Patterns

The bipartite network analysis identified specific roadways that contribute disproportionately to mortality. As hypothesized, deaths were not evenly distributed across the road network.

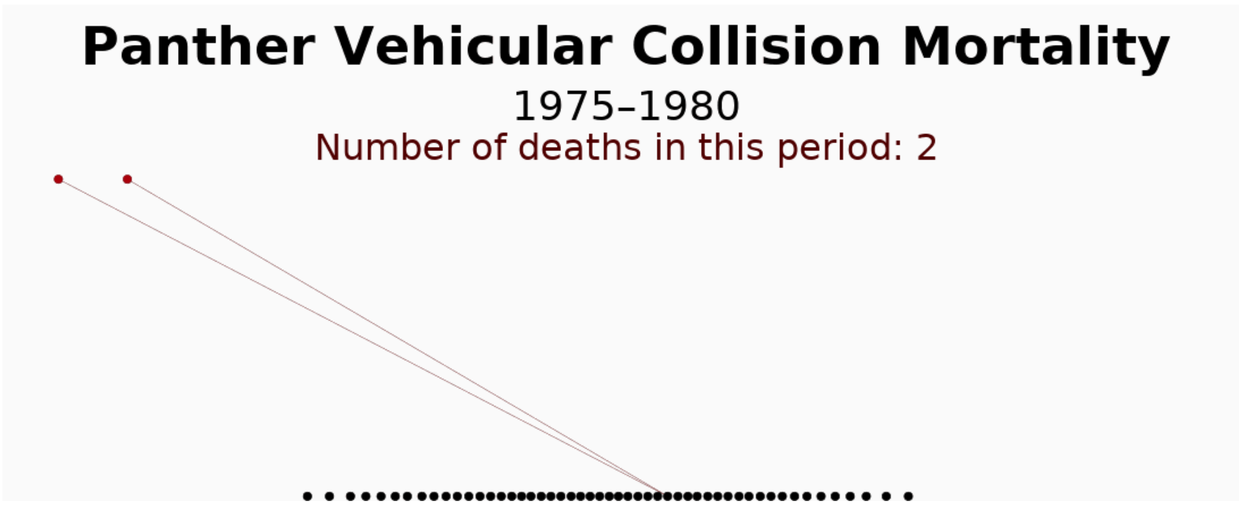

Figure 1. Temporal bipartite network visualizing panther deaths (red) against roads (black).

Community Detection and Biological Factors

The similarity networks provided the most distinct insights into demographic risks. The application of the Modularity algorithm resulted in three distinct major communities based on biological attributes.

When these communities were analyzed by sex, a clear separation emerged. Male and female mortalities formed distinct clusters within the network, confirming that the sexes interact with the road network differently.

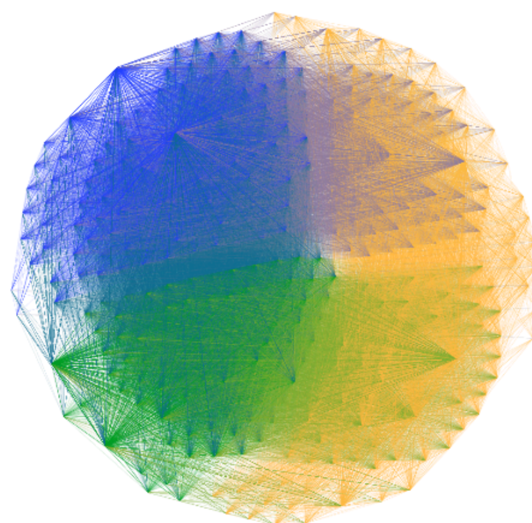

Figure 2. Community detection results on biological similarity network.

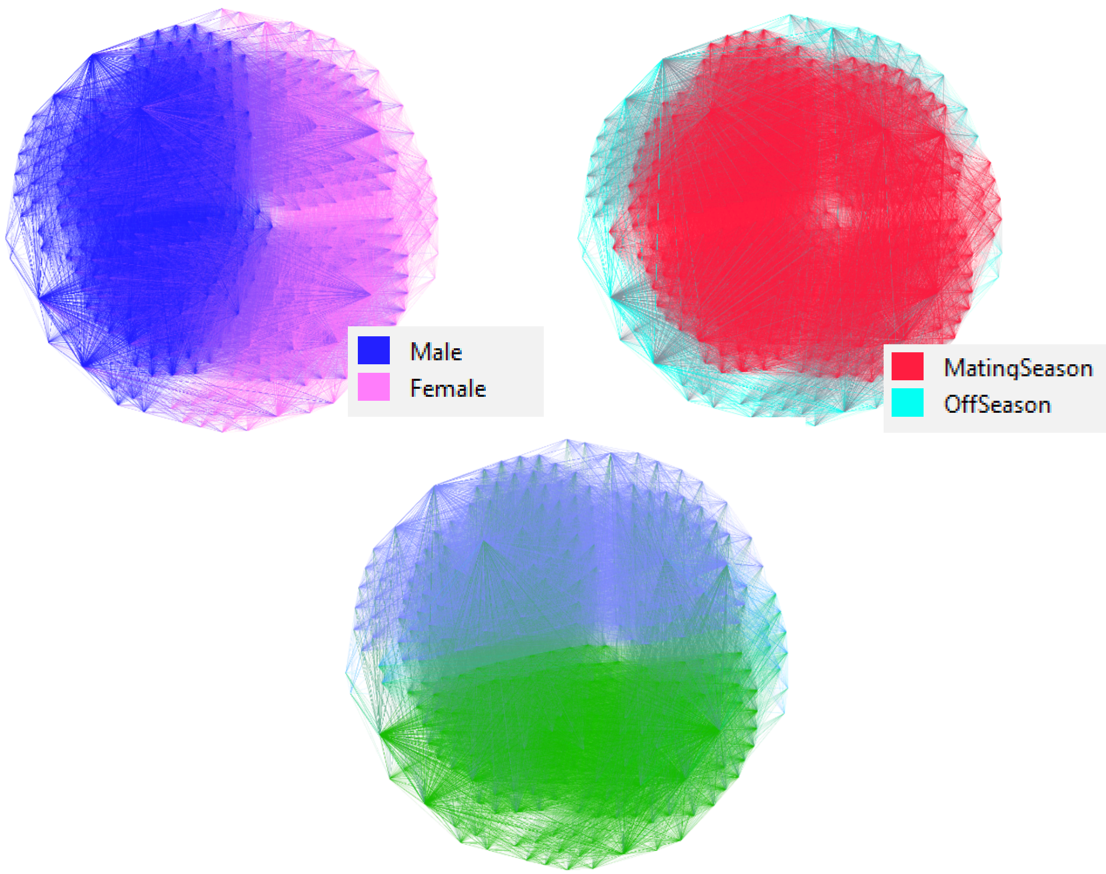

Figure 3. Variables that contributed to community detection results.

This clustering supports the literature stating that males are risk-takers with larger dispersal ranges, leading to different mortality patterns than females, who are more risk-averse regarding road crossings (Schwab & Zandbergen, 2011). Seasonality did not have a significant structural impact on the network. Approximately 80% of the deaths in the dataset occurred during the mating season (October through March). While this is a significant portion of the year, the network density during these months suggests that increased movement associated with mating behaviors exacerbates collision risk. Age class analysis showed that adults and subadults formed the bulk of the network structure, with kittens representing a smaller, less connected portion of the graph.

Road Type and Speed Limit Associations

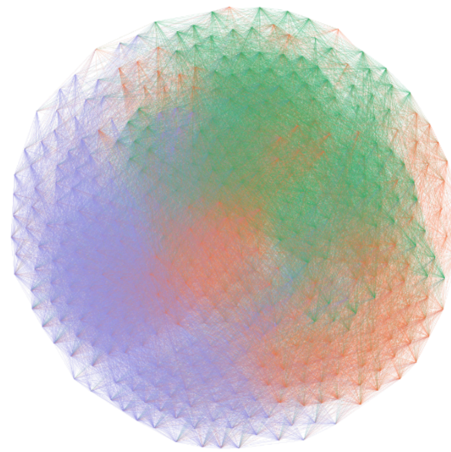

Figure 4. Community detection results on biological and human influence similarity network.

When road attributes were integrated into the similarity network, distinct communities formed around specific road classes and speed limits. The network analysis highlighted that State and County roads formed tighter clusters with mortality events than Federal or Local roads. Federal roads formed a smaller, isolated cluster, likely due to the presence of wildlife crossings and fencing on major interstates like I-75, which successfully mitigate mortality in those specific corridors (Taylor et al., 2002). Finally, a bipartite analysis of Road Type versus Sex illustrated the specific interaction between demographics and infrastructure.

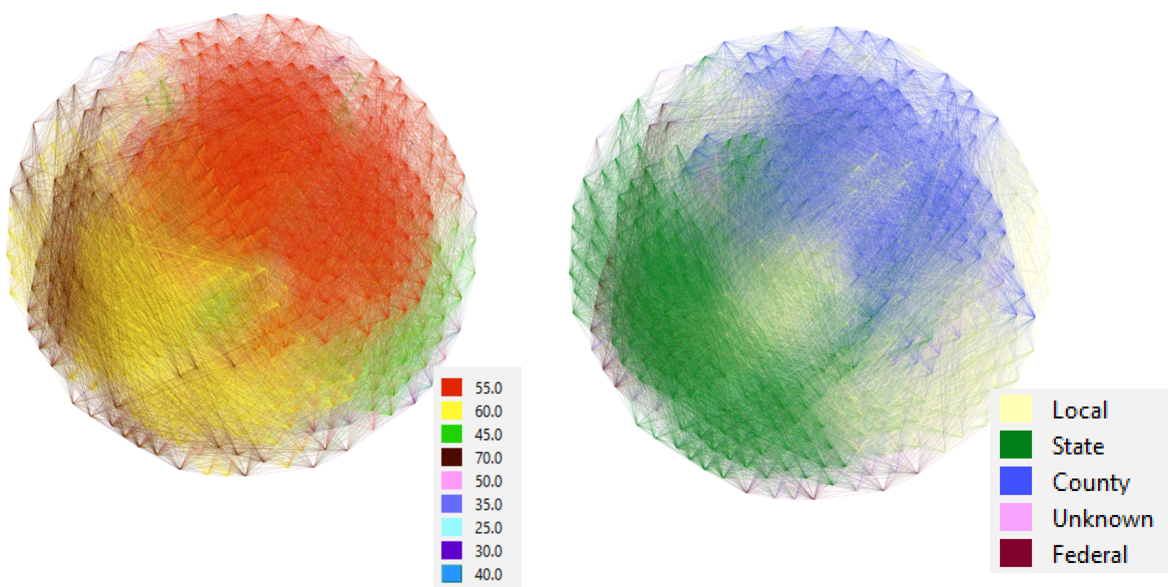

Figure 5. Human factor variables that contributed to community detection results.

This visualization (Figure 6) confirms that while both sexes die on State and County roads, the patterns of mortality on Federal roads are distinct, reinforcing the "barrier effect" hypothesis where females rarely attempt to cross these larger obstacles.

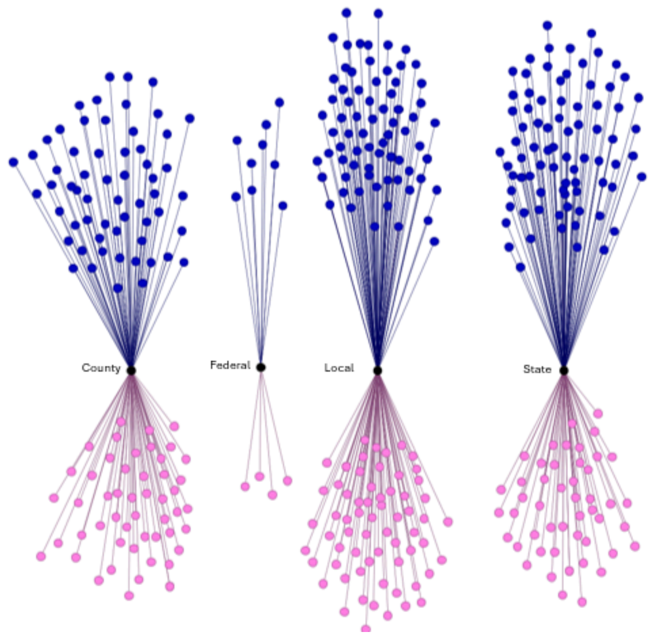

Figure 6. Bipartite network of male vs. female panther deaths compared to road classifications.

Conclusions

This study demonstrates that Florida panther deaths caused by vehicular collisions follow distinct biological and roadway-based patterns. The results confirm that sex, road type, and speed limit are dominant factors in shaping mortality communities. Specifically, adult males on State and County roads represent the highest-risk profile. This aligns with previous telemetry studies suggesting that males disperse farther and cross roads more frequently (Taylor et al., 2002). Furthermore, the clustering of mortalities on mid-sized roads suggests that current mitigation efforts, which have focused heavily on major interstates (Federal roads), have been effective there but leave a gap in protection on State and County routes.

There were limitations to this study. The dataset contained missing sex or age fields for some mortality events, which required the removal of those nodes from the similarity networks. Additionally, inconsistent road naming conventions across county borders may have introduced spatial errors in aggregation. Finally, as noted by Taylor et al. (2002) and McClintock et al. (2015), there is a likely underreporting of mortalities, particularly for uncollared panthers that may be injured by a vehicle but die away from the roadside, remaining undetected.

References

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Data Source:

Florida Fish and Wildlife Conservation Commission. (2025, August 22). Florida Panther mortality. ArcGIS Hub. https://hub.arcgis.com/datasets/3aa8eaa2a5ee4ce9912ad4d1edd8f613_7/about