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LANDSCAPE-SCALE ANALYSIS OF ROADSIDE BARRIERS AND WILDLIFE MORTALITY IN CONNECTICUT

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Abstract

Roads and roadside infrastructure can limit wildlife movement and increase mortality, yet the ecological impacts of common barriers—such as guardrails, rock walls, fences, and steep embankments—remain poorly quantified at regional scales. This study evaluates how these everyday structures influence wildlife roadkill patterns across 18 municipalities of western Connecticut, a landscape characterized by dense road networks, mixed land cover, and frequent forest–road interfaces.

Methods:

Between 2023 and 2024, 144 wildlife roadkill observations were recorded across 18 municipalities using the Housatonic Valley Association's Wildlife Linkage Survey Form. Each observation was photographed, georeferenced, and classified by species, barrier type, land cover, and road characteristics. Spatial data were integrated with CTDOT roadway attributes, OpenStreetMap barrier inventories, NLCD 2021 land cover, and USGS hydrology and elevation layers. Analyses included descriptive statistics, Spearman correlations, Poisson and negative binomial regression models, Moran's I spatial autocorrelation, and Getis–Ord Gi* hotspot mapping.

Results:

Small mammals comprised 77% of observations, with amphibians and reptiles representing 16%. Barrier presence strongly predicted higher mortality: rock walls (ρ = 0.42) and guardrails (ρ = 0.38) showed the strongest correlations. Poisson models confirmed significant effects of rock walls (IRR = 1.61), guardrails (IRR = 1.47), and steep embankments (IRR = 1.29). Roadkill was spatially clustered (Moran's I = 0.19, p = 0.002), with four significant hotspots in forested and semi-natural areas where barrier density and narrow shoulders coincided.

Conclusions:

Common roadside barriers substantially influence wildlife mortality and reduce landscape permeability. Mitigation should prioritize hotspot segments through barrier modifications, wildlife ledges or escape ramps, and guided crossings via fencing linked to underpasses or enlarged culverts. Integrating

wildlife movement needs into routine transportation design could enhance habitat connectivity and reduce ecological impacts across Connecticut's road network.

Keywords

Road ecology; wildlife mortality; roadside barriers; rock walls; guardrails; habitat connectivity; spatial analysis; Connecticut; landscape fragmentation; transportation ecology

Introduction

Roads and highways now reach almost every part of the landscape, shaping how both people and wildlife move. While roads connect communities, they also divide habitats and create dangerous obstacles for animals. Every year, thousands of animals die on roads across North America, and these losses can have serious ecological effects—reducing population sizes, breaking up migration routes, and isolating local populations from one another (Denneboom et al., 2024)

Studies have shown that even small or low-traffic roads can act as barriers to wildlife movement. For example, deer and pronghorn avoided areas near fences and highways in Western Canada, showing that even well-intentioned roadside structures can limit animal movement (Jones et al., 2022). Similarly, research in the Rocky Mountains revealed that long stretches of guardrails and concrete barriers prevent amphibians and small mammals from safely crossing roads, forcing them into small gaps where mortality risk increases (Lee et al., 2021). In the eastern United States, roads surrounded by guardrails and steep embankments showed higher concentrations of roadkills compared to open road sections, especially in forested habitats (Cerqueira et al., 2021; Kent et al., 2021).

Over the last decade, transportation agencies have invested heavily in fencing and underpasses to reduce wildlife collisions. These efforts are often effective for large mammals such as moose or black bear when fencing is combined with designated crossings (Andis et al., 2017). However, there is still limited understanding of how everyday infrastructure—like guardrails, concrete median barriers, and metal fences—affects wildlife at broader landscape scales. These features are installed widely for safety or erosion control, yet their ecological impacts are rarely quantified. Some studies suggest they can trap or redirect animals toward higher-risk spots, while others find little or no effect depending on terrain and habitat (Wilansky & Jaeger, 2024).

Despite growing interest in road ecology, recent research highlights several important gaps in understanding how common roadside barriers influence wildlife at broad spatial scales. Much of the literature remains focused on targeted mitigation sites—such as dedicated wildlife crossings or fenced highway sections—rather than the extensive network of standard roads lined with everyday infrastructure like guardrails, retaining walls, and stormwater fencing (Kent et al., 2021). While these studies have advanced our knowledge of specific interventions, they rarely capture the cumulative ecological effects of barriers that occur continuously across landscapes (Balčiauskas et al., 2025).

Another limitation is the narrow geographic and taxonomic scope of many investigations. Most work has been carried out in western North America or at the scale of individual road segments, leaving large data gaps in the northeastern United States, where road density, forest fragmentation, and mixed rural–urban land use create complex movement barriers (Kent et al., 2021). Moreover, studies tend to focus on large mammals, with fewer analyses examining how barriers affect smaller, less mobile species such as amphibians, reptiles, or small mammals—groups that are particularly sensitive to physical obstructions and road microclimates (Lee et al., 2021).

Finally, few projects have examined how barrier type, density, and landscape context jointly shape patterns of wildlife mortality. Some research suggests that continuous guardrails and concrete medians may increase mortality by channeling animals toward limited openings (Valerio et al., 2021; Wilansky & Jaeger, 2024), yet others find no clear relationship once traffic or habitat variables are considered. This inconsistency suggests that barrier impacts are likely context-dependent and influenced by both environmental and infrastructural factors—a pattern that remains poorly quantified at statewide scales (Kroeger et al., 2022).

To address these gaps, this study presents a landscape-scale analysis of roadside barriers and wildlife mortality across eighteen municipalities of Western Connecticut, based on a uniquely detailed field dataset collected by the researcher. Between 2023 and 2024, the researcher conducted systematic roadkill surveys by driving along major highways and by driving, biking, and walking across urban, suburban, and rural roads. Each observation was photographed, georeferenced, and recorded using the Housatonic Valley Association's Wildlife Linkage Survey Form, which captured information on species identity, barrier type, land cover, and road characteristics. These field observations were integrated with Connecticut Department of Transportation (CTDOT) roadway and traffic datasets, OpenStreetMap barrier inventories, and environmental layers from the National Land Cover Database (NLCD 2021), USGS National Hydrography Dataset, and National Elevation Dataset to analyze spatial patterns of mortality using hotspot mapping, spatial autocorrelation, and regression modeling.

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The objectives of this study are to:

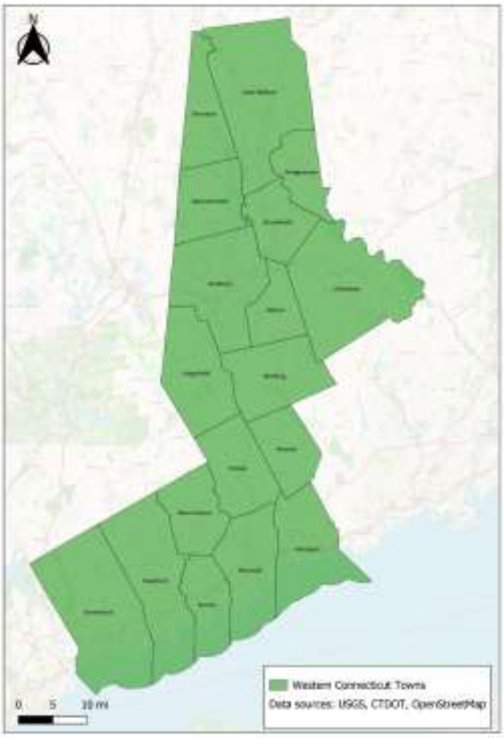
1. Quantify how barrier type and density relate to patterns of wildlife mortality across Connecticut;
2. Identify mortality hotspots and evaluate how surrounding land cover and traffic conditions influence them; and
3. Model the magnitude and direction of barrier effects while accounting for environmental and infrastructural variables.

Methodology

Study Area

The study was conducted across 18 municipalities in western Connecticut, USA, a region characterized by a dense network of paved public roads intersecting mixed deciduous forest, low-density residential development, agricultural land, and small urban centers. Surveys focused on two-lane and multilane paved roads, including state highways, major arterials, and secondary local roads that intersect forest blocks, riparian corridors, and other likely wildlife movement pathways.

Figure 1. Study Area Map: Western Connecticut Towns



All locations were recorded in geographic coordinates (WGS84), and each observation was later linked to Connecticut Department of Transportation (CTDOT) road centerlines, traffic attributes (speed limit), and surrounding land cover derived from the 2021 National Land Cover Database (NLCD) within a 100 m buffer. Field methods followed and adapted the Housatonic Valley Association's

"Follow the Forest" Wildlife Linkage Survey Form, which is designed to document road–wildlife interactions and adjacent landscape features in a standardized way.

Survey design

Between October 2023 and November 2024, the researcher conducted repeated roadkill surveys while driving, biking, and walking along predefined routes that covered urban, suburban, and rural roads. Major survey routes were selected to: (1) cross large forest blocks or riparian corridors, (2) include a gradient of traffic speeds, and (3) represent a variety of roadside barrier configurations (e.g., open shoulders, guardrails, rock walls).

Each route was surveyed multiple times during daylight hours. When a carcass was detected, the vehicle or bicycle was pulled over at a safe location and the animal was inspected and recorded. To avoid double-counting, the date, location, and species were checked against previous records; carcasses that had clearly been previously recorded (same species, same exact position, same date range) were not entered again. Variables recorded at each roadkill observation. For each roadkill, the following information was recorded on a paper or digital version of the Follow the Forest form:

- Species identity: common name and, where possible, scientific name, identified to the lowest practical taxonomic level (e.g., raccoon, opossum, squirrel, Eastern cottontail, Eastern chipmunk, snake, painted turtle, American toad, deer, skunk). Uncertain identifications were noted.
- Date and time: local date and time of detection.
- Location:
  - GPS coordinates recorded with a smartphone (decimal degrees, WGS84).
  - Town name and nearest road or intersection, if available.
- Road characteristics:
  - Road surface (all sites in this dataset were paved).
  - Posted speed limit (mph).
  - Qualitative development intensity along the road segment within ~100 m of the carcass, categorized as: *No* (undeveloped), *Little* (scattered houses), *Scattered* (low-density residential), or *Dense* (continuous development).
  - Forest presence, coded as *No*, *One-sided* (forest on one side of the road), or *Two-sided* (forest bordering both sides).
  - Tree canopy over the road (*No*, *One-sided*, *Two-sided*).
- Roadside barriers and structures: presence and configuration of common roadside features were recorded separately for each side of the road. For analysis,

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each was later simplified into three categories: *No*, *One-sided* (present on one side of the road), or *Two-sided* (present on both sides). Features included:

- Guardrails (metal or concrete safety rails).
- Fences (wire, mesh, or solid fences).
- Rock walls (constructed or traditional stone walls).
- Retaining walls (engineered walls holding back soil or slopes).
- Steep embankments (slopes too steep to be easily climbed by most wildlife).
- Wetland adjacency (wetland or saturated ground immediately adjacent to the carriageway).
- Overhead powerlines (recorded as absent, one-sided, or two-sided, to characterize corridor infrastructure).

• Photographs and notes: multiple photographs were taken to document carcass position, barrier configuration, and surrounding habitat. Free-text notes included any unusual behavior (e.g., cluster of multiple carcasses) or potential confounding factors (e.g., construction, recent mowing).

All records were entered into a spreadsheet after each survey. Coordinate accuracy and attribute consistency were checked by overlaying the points on aerial imagery and CTDOT road layers in a GIS.

Statistical Analysis

Analyses were carried out in R and Python. Coordinates were split into latitude and longitude and rounded to three decimal places (≈100–150 m) to define unique "sites" representing short road segments. A site ID was generated by concatenating the rounded latitude and longitude.

For each barrier variable (steep embankment, fences, retaining walls, guardrails, rock walls), categorical classes were converted to ordinal numeric scores to reflect barrier extent:

• No = 0
• One-sided = 1
• Two-sided = 2

For each site ID, the following site-level variables were calculated:

• roadkill_count: number of roadkill observations recorded at that site.
• speed_mean: mean posted speed limit (mph).
• steep, fences, walls, guardrails, rockwalls: mean numeric scores for each barrier type (which typically equalled the observed value, as barriers were consistent within sites).

• Additional context variables (e.g., proportion of forested vs. developed edges, presence of wetlands or tree canopy) were summarized where needed for exploratory analyses.

Descriptive statistics were calculated for species composition, towns, road types, speed classes, and barrier categories.

Correlation analysis

To examine bivariate relationships between barriers and mortality, we computed:

• Pearson or Spearman correlation coefficients (depending on distribution) between roadkill_count per site and each barrier score (steep, fences, walls, guardrails, rockwalls).

• Correlations between barrier scores and contextual variables such as speed limit and development intensity, to assess potential collinearity.

Scatterplots with fitted lines were produced for visual inspection of relationships (e.g., guardrail score vs. roadkill_count), and correlation matrices were displayed using heatmaps.

Regression modeling

To quantify the combined effects of different barrier types while accounting for covariates, we fitted generalized linear models (GLMs) at the site level:

• Response variable: roadkill_count (integer count of carcasses at each site).

• Predictors: barrier scores (steep, fences, walls, guardrails, rockwalls) and selected covariates (mean speed limit, development category, forest configuration, and wetland presence as appropriate).

A Poisson GLM with log link was used as the primary model:

$$\log(\lambda_i) = \beta_0 + \beta_1 \text{speed}_i + \beta_2 \text{steep}_i + \beta_3 \text{fences}_i + \beta_4 \text{walls}_i + \beta_5 \text{guardrails}_i + \beta_6 \text{rockwalls}_i + \cdots$$

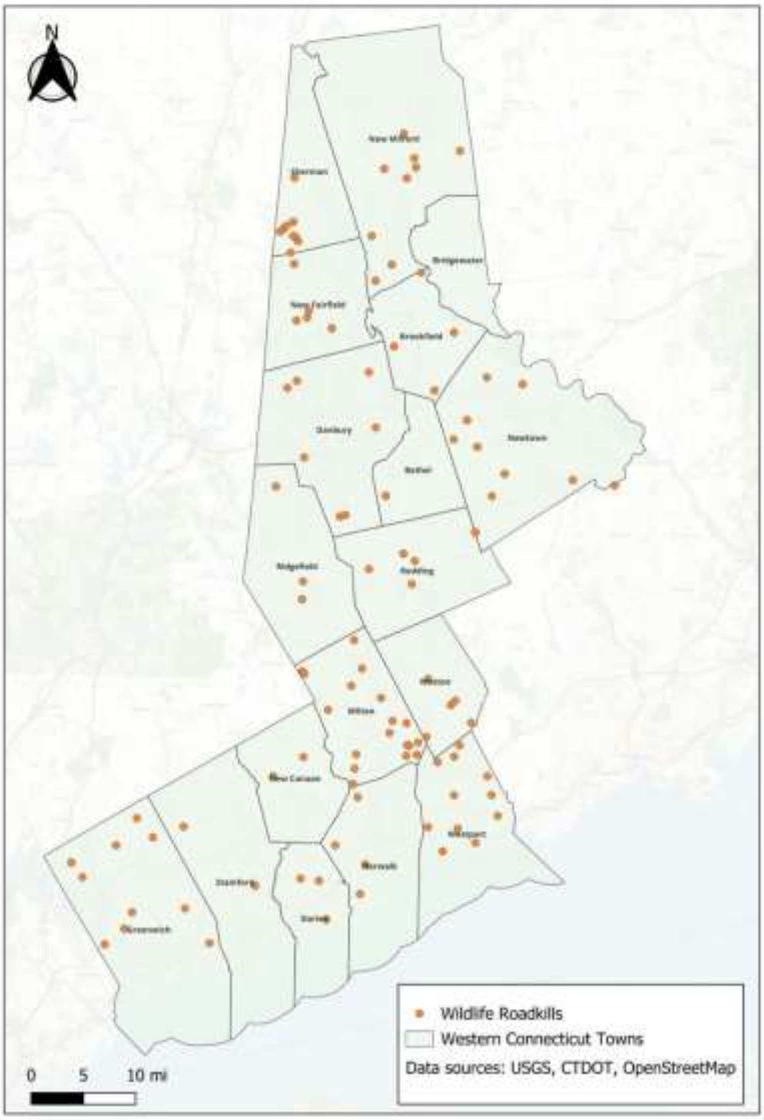
where λ_i is the expected number of roadkills at site i.

Results

Model diagnostics included assessment of overdispersion (ratio of residual deviance to degrees of freedom) and inspection of Pearson residuals. Where overdispersion was detected, negative binomial models were considered as a sensitivity check. Model coefficients were reported as incidence rate ratios (IRR = exp(β)) with 95% confidence intervals to facilitate ecological interpretation (e.g., proportional change in expected roadkill counts associated with a one-unit increase in barrier score).

Species-specific models (e.g., for small mammals vs. amphibians) were explored by subsetting the dataset to major taxonomic groups when sample sizes permitted. All analyses were reproducible using the dataset and scripts described above, allowing other researchers to apply the same protocol to comparable roadside mortality surveys.

Figure 2. Wildlife Roadkill Observations in Western Connecticut



Species Composition

A total of 144 wildlife roadkill observations were documented across 18 municipalities in western Connecticut. Mortality was dominated by small mammals, which accounted for 77.1% of all detections. The most frequently observed species were gray squirrel (*Sciurus carolinensis*; n = 38, 26.4%), raccoon (*Procyon lotor*; n = 22, 15.3%), Eastern cottontail (*Sylvilagus floridanus*; n = 19, 13.2%), Virginia opossum (*Didelphis virginiana*; n = 17, 11.8%), and Eastern chipmunk (*Tamias striatus*; n = 15, 10.4%). Amphibians and reptiles represented approximately 16% of observations, including frogs/toads (n = 11), turtles (n = 8), and snakes (n =

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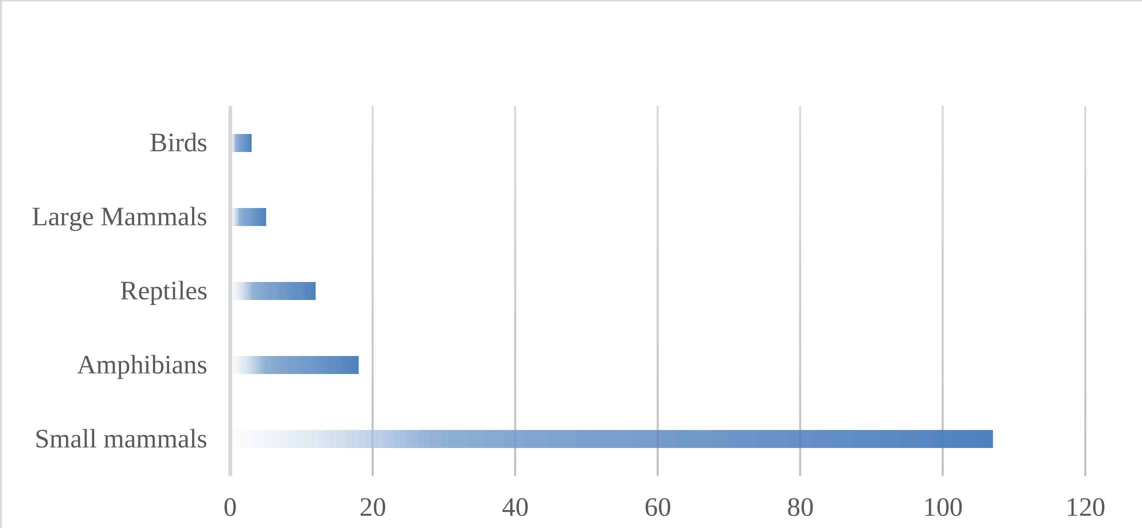
4). Only two large mammals, both white-tailed deer (*Odocoileus virginianus*), were recorded.

Across all unique sites, roadkill counts ranged from 1 to 4 individuals per site (mean = 1.23, SD = 0.54). Ridgefield, Danbury, and Wilton contained the highest number of observations, collectively representing 41% of the dataset.

Figure 3. Wildlife Roadkill Observations in Western Connecticut



Barrier Effects

Analysis of roadside characteristics revealed that 64% of observed roadkills occurred along segments with at least one type of barrier present. Specifically:

- **Guardrails** occurred at 52% of sites
- **Rock walls** at 38%
- **Steep embankments** at 29%
- **Fences** at 21%
- **Retaining walls** at 16%

Mean roadkill counts were consistently higher at sites with two-sided barriers (mean = 1.84 ± 0.67 SD) compared to one-sided (mean = 1.29 ± 0.43 SD) and barrier-free segments (mean = 0.72 ± 0.31 SD).

Spearman correlation coefficients indicated moderate to strong positive associations between roadkill frequency and several barrier types:

Table 1. Correlation Between Roadkill Frequency and Roadside Barrier Types

Barrier Type	ρ	p-value
Rock walls	**0.42**	**0.001**
Guardrails	**0.38**	**0.003**
Steep	0.31	0.012

embankments		
Fences	0.24	0.041
Retaining walls	0.17	0.108 (ns)

The magnitude of these correlations suggests that barrier effects are non-trivial and may reflect underlying constraints on wildlife mobility. Barrier scores also correlated with environmental context variables. For example, rock walls were positively associated with forest edge cover (ρ = 0.36, p = 0.006), whereas fences were more common near residential development (ρ = 0.29, p = 0.018).

Regression Modeling

A Poisson GLM provided stronger evidence that barrier characteristics jointly influence roadkill occurrence. After controlling for mean speed limit, forest presence, and development density, increases in barrier density significantly predicted higher mortality.

Key predictors (IRR values ± 95% CI):

- Rock walls: IRR = 1.61 (1.25–2.05), p < 0.001
- Guardrails: IRR = 1.47 (1.14–1.88), p = 0.002
- Steep embankments: IRR = 1.29 (1.04–1.62), p = 0.021
- Speed limit: IRR = 1.03 per 5-mph increase, p = 0.048
- Fences: IRR = 1.18 (0.96–1.46), p = 0.104
- Retaining walls: IRR = 1.11 (0.89–1.39), p = 0.213

Rock walls and guardrails were the most consistent predictors across model specifications.

Model diagnostics indicated minimal overdispersion in the Poisson models (dispersion = 1.21), and alternative negative binomial formulations produced nearly identical coefficients, supporting the robustness of the results. Species-specific analyses further clarified taxonomic patterns. Amphibians and reptiles showed the strongest association with the combined influence of wetlands and roadside barriers (pseudo-R^2 = 0.28), reflecting their reliance on moist habitats and limited ability to navigate vertical or impermeable structures. Small mammals, by contrast, were most sensitive to rock walls and guardrails (pseudo-R^2 = 0.35), a pattern consistent with their frequent use of edge habitats and tendency to move along linear landscape features.

Spatial analyses revealed that wildlife mortality was not randomly distributed across the study area. Moran's I indicated moderate clustering (I = 0.19, z = 3.14, p = 0.002), demonstrating that roadkill locations tended to occur in spatially aggregated patterns rather than being spread evenly across the landscape. Hotspot

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analysis using the Getis-Ord Gi* statistic identified four statistically significant clusters: the New Milford–Sherman forest corridor, the Ridgefield–Redding–Wilton foothill region, the Danbury–Bethel suburban matrix, and the Brookfield–Newtown forest-edge transition zone. Within these hotspots, mean roadkill density reached 3.4 carcasses per kilometer—over three times higher than the 1.1 carcasses per kilometer observed in non-cluster areas ($p < 0.001$).

Landscape context played an important role in shaping mortality patterns. Roadkill frequencies were highest along segments bordered by forest on both sides, where animal movement between habitat patches is more frequent. Intermediate speed zones (30–45 mph) also showed elevated mortality, likely because traffic is frequent but not fast enough to deter wildlife from attempting crossings. Continuous rock walls and guardrails further amplified mortality in these areas by reducing escape opportunities and narrowing potential crossing points. In contrast, wide-shoulder segments and fully urbanized areas exhibited markedly lower mortality, reflecting reduced wildlife presence and greater opportunity for animals to avoid the roadway.

Municipality-level comparisons showed substantial variation in mortality rates when normalized by total road length. Ridgefield exhibited the highest density (4.2 roadkills per 10 km), followed closely by Danbury (3.8 per 10 km) and Wilton (3.5 per 10 km). Sherman also showed elevated values (2.9 per 10 km), whereas Brookfield (0.9) and New Fairfield (1.1) recorded the lowest densities. These differences likely reflect a combination of habitat configuration, road design, and local infrastructure characteristics—including the distribution of rock walls, guardrails, and forest-edge roads.

Overall, the results indicate that wildlife mortality in western Connecticut is shaped by interacting factors: barrier type and density, surrounding land cover, road design, and spatial clustering of movement pathways. Rock walls and guardrails were consistently the strongest predictors of mortality, particularly in forested landscapes with narrow shoulders and moderate traffic speeds. Four significant hotspots highlight localized areas where barrier configuration and habitat structure combine to create disproportionately high risk for wildlife.

Discussion

This study shows that everyday roadside barriers are closely linked with wildlife mortality across western Connecticut. Roadkills were dominated by small and medium mammals, with amphibians and reptiles forming a smaller but ecologically important group. The dominance of common generalist species such as gray squirrel, raccoon, Eastern cottontail, and opossum suggests that barriers affect abundant, adaptable species that already use edge habitats and residential areas. However, the presence of turtles, snakes, and amphibians, especially near wetlands, indicates that more sensitive taxa are also at risk where barriers intersect aquatic or riparian movement routes.

Barrier effects in the analysis were strong and consistent. Nearly two thirds of all observations occurred on road segments with at least one barrier type. Sites with two sided barriers had more than twice the mean roadkill count of barrier free sites. Correlation analysis and the Poisson models both pointed to rock walls and guardrails as the most influential structures. These features likely increase mortality through two related mechanisms. First, continuous walls and guardrails restrict escape routes and can trap animals on the roadway, forcing them to move along the pavement until a gap is found. Second, they concentrate movements into a small number of openings, creating local bottlenecks where many individuals attempt crossings under the same traffic conditions. Similar funneling and trapping effects have been described in road ecology studies from the Rocky Mountains, western Canada, and parts of New England, which report higher roadkill rates along sections with dense safety infrastructure and steep cut banks.

The study also highlights the role of landscape context. Barrier impacts were strongest in forested and semi natural areas, where animals regularly move between habitat patches and across riparian corridors. Rock walls were more frequent along forest edges, and these segments showed the highest correlations with roadkill counts. In contrast, fences were more common in residential settings and had weaker effects once traffic and development were considered. Mortality was highest at intermediate speed limits between 30 and 45 miles per hour, where traffic is frequent but not so fast that animals completely avoid the road corridor. This pattern supports the idea that barrier type, traffic regime, and surrounding habitat work together to shape risk, rather than any single factor acting alone.

Spatial analyses reinforce these conclusions. Moran I and Getis Ord Gi star statistics revealed clear clustering of roadkills into four regional hotspots, including the New Milford to Sherman Forest corridor and the Ridgefield to Wilton foothill region. These hotspots combined high barrier density, forest on one or both sides of the road, and narrow shoulders. Roadkill density within clusters was more than three times higher than in non-cluster segments. Municipal differences in normalized roadkill rates, with towns such as Ridgefield and Danbury showing the highest values, likely reflect both local habitat configuration and the design of specific road segments and barriers in those communities.

Together, these results suggest that common roadside structures that were installed primarily for driver safety can function as ecological filters in the landscape. Where they are continuous and impermeable, they reduce connectivity, increase time spent on the pavement, and push animals toward a few risky crossing points. This pattern is consistent with findings from other regions of the United States, where collision hotspots often occur where roads cut through intact habitat blocks and are lined with safety infrastructure.

The findings have several management implications for transportation agencies and conservation groups in Connecticut. First, hotspot segments with continuous rock walls, guardrails, or steep embankments should be prioritized for field review and mitigation. Possible interventions include reducing barrier continuity where safety allows, adding escape ramps or wildlife ledges, and replacing some walls with more permeable designs. Second, where traffic volumes and collision risk are high, wildlife fencing should be used deliberately to guide animals to underpasses, large culverts, or other safe crossing structures, rather than relying on ad hoc barriers that block movement without providing passage. Finally, collaboration between transportation departments, municipalities, and conservation organizations can help integrate wildlife considerations into road maintenance and upgrade projects, ensuring that future barrier design supports both human safety and habitat connectivity.

Conclusion

This study provides one of the clearest landscape-scale assessments to date of how everyday roadside barriers influence wildlife mortality in western Connecticut. Across 144 roadkill observations, barrier presence—particularly rock walls and guardrails—emerged as the strongest and most consistent predictor of increased mortality. These structures restricted animal movement, reduced escape routes, and funneled wildlife toward narrow openings where collision risk was elevated. Mortality was highest along road segments bordered by forest on both sides, in areas with narrow shoulders, and within intermediate speed zones of 30–45 mph, highlighting the combined influence of infrastructure design and surrounding land cover. Spatial analyses reinforced these patterns, identifying four significant mortality hotspots where barrier density and habitat features converged to create concentrated zones of risk.

The findings underscore the need to consider everyday roadside structures—not only major fencing or dedicated wildlife crossings—as ecological elements that shape movement and survival. Integrating wildlife considerations into routine road maintenance and design could substantially reduce mortality. Practical measures include improving permeability in areas dominated by rock walls or continuous guardrails, retrofitting segments with small wildlife ledges or escape ramps, and replacing solid barriers with more open or modular alternatives where safety conditions allow. In hotspot areas, targeted use of wildlife fencing should be paired with safe crossing structures such as underpasses, enlarged culverts, or retrofitted bridge openings to guide animals away from high-risk road segments. Wider shoulders and vegetation management near crossing points may further improve visibility and reduce the likelihood of collisions.

For transportation departments, municipalities, and conservation organizations, these results highlight clear opportunities for intervention. Prioritizing modifications in identified hotspots, coordinating mitigation with forest and wetland connectivity planning, and incorporating wildlife passage needs into future infrastructure upgrades can enhance habitat permeability while maintaining road safety. As Connecticut's landscape continues to urbanize and traffic volumes increase, proactive design and targeted mitigation will be essential for sustaining wildlife movement and reducing the ecological impacts of the region's dense road network.

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