AMERICAN BLACK BEAR (*URSUS AMERICANUS*) USE OF HIGHWAY UNDERPASSES IN NORTHERN NEW JERSEY

by

Victoria Alves

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Degree in Wildlife Ecology and Conservation with Distinction

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ABSTRACT

The state of New Jersey balances a large human population with associated transportation infrastructure and urban development with an ecological diversity that encompasses many species and habitat types. One key member of that ecological diversity is the American black bear (*Ursus americanus*), a quintessential omnivore found throughout the state despite many major roadways that could pose barriers to movement and habitat connectivity. Here I examine black bear movement dynamics at existing underpass structures of major roadways in Northern New Jersey. We monitored 37 potential crossing structures along State Route 1, Interstate 78, Interstate 80, Interstate 95, State Route 202, and State Route 206, using trail cameras. My findings suggest that the current North Atlantic Aquatic Connectivity Collaborative metric used to assess underpasses for bear use may not accurately predict bear use, and that habitat related factors, specifically the amount of core habitat in the area surrounding each underpass, may provide a stronger predictive basis for where a bear crossing might occur. These findings can be used to better inform the future placement or enhancement of crossing structures for use by black bear. This will be important in the continued management of human-wildlife conflict in the most densely population state in the nation.

INTRODUCTION

The American black bear (*Ursus americanus*, hereafter black bear or bear) is North America's most widely distributed bear species, found in a diverse array of habitats from north to south and coast to coast (Scheick and McCown 2014). Black bear population density and behavior vary with habitat and their more secretive nature can make them difficult subjects to study (Pelton 2003). However, as a popular game species, local species of concern, and human-wildlife conflict species, many topics of bear biology have been well researched (Ingram et al. 2012), including movement activities. Black bear movement across a landscape is influenced by a variety of factors, with one of the most prominent and universal being food availability, which motivates habitat use and selection (Costello and Sage 1994; Koehler and Piece 2003). That movement can be altered or inhibited by landscape factors, especially those associated with urban environments, like increased road density (Zeller et al. 2019). Previous studies have also suggested the timing, speed, and location of bear movement can be impacted by road presence and size (Zeller et al. 2019).

The continuous expansion of roadways across the United States is an ongoing topic of wildlife research and concern (Coffin 2007). Roads can pose a barrier to free movement across a landscape, thus fragmenting habitat, isolating subpopulations, and limiting gene flow (Forman and Alexander 1998). Over time, this threatens the health and longevity of a species in a given area, with habitat fragmentation directly linked to population decline (Wiegand et al. 2005). In black bears specifically, habitat fragmentation has already resulted in significant genetic differentiation within some populations, causing concern for long-term persistence in places like Florida (Dixon et al. 2006). However, the implementation of underpasses along roadways can allow movement across roads, potentially preventing issues associated with habitat fragmentation for a variety of species, including black bear (Van Manen et al. 2012). A true underpass is any structure that allows the flow of traffic under a roadway, be it vehicular, pedestrian, or otherwise. This paper focuses on wildlife underpasses, which are wildlife-specific crossing structures used to connect habitat areas intersected by roadways (Caldwell and Klip 2019). The wildlife underpasses, hereafter underpasses, in this study were culvert and bridge structures.

The state of New Jersey has one of the most extensive road systems in the United States, with approximately 39,000 miles of public roadways spanning twenty-one counties, all of which are classified as urban by the U.S. Census Bureau (New Jersey Department of Transportation 2024). Additionally, over forty percent of the state is covered in traditional forests, creating a unique urban-forest interface marked by different forested habitats and large roadways (New Jersey Forest Service 2025). Those roadways are an especially prominent landscape element in north and central New Jersey and could threaten habitat connectivity, but existing underpass infrastructure may reduce the impacts of fragmentation for wildlife species (North Atlantic Aquatic Connectivity Collaborative 2025a).

There have been several previous efforts to evaluate underpasses throughout the United States, including the North Atlantic Aquatic Connectivity Collaborative (NAACC) (North Atlantic Aquatic Connectivity Collaborative 2025a). The NAACC has spent the last decade creating a unified assessment system to evaluate passability through aquatic and terrestrial underpasses and assessing underpasses from Maine to West Virginia (North Atlantic Aquatic Connectivity Collaborative 2025a). The NAACC's regional underpass examinations for terrestrial connectivity include species-specific scores that quantify passability for terrestrial wildlife at individual underpass sites (North Atlantic Aquatic Connectivity Collaborative 2025a). These scores take into account the physical characteristics of each underpass, including dimension, line of sight, and any obstacles to free passage (North Atlantic Aquatic Connectivity Collaborative 2025b).

While NAACC scores aim to evaluate underpasses themselves from a wildlife lens, these physical properties are not the sole motivators of wildlife moving throughout road-afflicted landscapes. Elements of the surrounding habitat can also play an important role in terrestrial wildlife movement and how often an underpass is used (Denneboom et al. 2023). The Connecting Habitat Across New Jersey (CHANJ) effort through the New Jersey Fish and Wildlife agency has mapped key areas across the state for terrestrial wildlife habitat connectivity, including core habitat areas, corridors that connect them, and road segments that may pose barriers to free movement between those core and corridor areas (New Jersey Department of Environmental Protection 2025). These local habitat evaluations can supplement NAACC's assessments to provide an encompassing picture of individual underpasses in New Jersey and the landscapes surrounding them.

Black bear are native to New Jersey and currently inhabit most counties across the state, but their movement and habitat use in this area of the United States is widely under researched (New Jersey Division of Fish and Wildlife 2025; Tri et al. 2016). Here I aim to increase that body of knowledge by examining black bear movement through existing underpass sites along multiple highways in New Jersey. I will compare observed bear use to terrestrial passage scores (NAACC), the linear distance to nearest core or corridor area (CHANJ), and the proportion of core habitat area (CHANJ) within the radius of an average female black bear home range. My goal is to determine if existing infrastructure is conducive for black bear habitat connectivity in New Jersey and to provide insight into how bears move across urban and road-dense areas. My findings can inform future underpass placement, and current underpass renovation, to facilitate black bear movement across the state of New Jersey.

METHODS

Study Area

I used data from 80 camera traps set at 37 sites along State Route 1, Interstate 78, Interstate 80, Interstate 95, State Route 202, and State Route 206 (Figure 1). These roadways were prioritized based on the potential impediment to bobcat (*Lynx rufus*) movement, however they are still ideal for our understanding of bear use. From north to south, these six roadways reside within the Skylands, Piedmont and Inner Coastal Plain, and Pinelands Conservation Focal Areas of New Jersey (New Jersey Department of Environmental Protection 2018).

The Skylands Landscape Region encompasses Sussex, Warren, Hunterdon, Somerset, Passaic, Essex, Bergen, and Morris counties, and is home to forest, forested wetland, and scrub-shrub habitat (New Jersey Department of Environmental Protection 2018). While there are many high-quality forests in this area, threats to all habitat types include lack of proper management, over-browsing by deer, a lack of sunlight in many understory areas, and invasive species. These factors particularly threaten scrub-shrub habitat, which is uncommon (New Jersey Department of Environmental Protection 2018).

The Piedmont and Inner Coastal Plain Landscape Region is a combination of two physiographic regions – the Piedmont and Inner Coastal Plain – and encompasses Burlington, Gloucester, Salem, Mercer, Middlesex, Monmouth, Hunterdon, Somerset, Union, Essex, Hudson, Passaic, and Bergen counties. This region is home to a variety of waterways, farmlands, grasslands, fragmented woodlands, and tidal freshwater marshes (New Jersey Department of Environmental Protection 2018). Major threats in this area include past and continued human development, invasive species, over-browsing by deer, and sea level rise in tidal freshwater marshes specifically (New Jersey Department of Environmental Protection 2018).

The Pinelands Landscape Region encompasses Atlantic, Ocean, Burlington, Camden, and Gloucester counties, and is home to pine and pine-oak mesic upland forests, pitch pine lowlands, cedar swamps, and other wetland and waterway systems (New Jersey Department of Environmental Protection 2018). This region has well-managed and healthy forest and wetland ecosystems, though threats still exist in the form of climate change due to low topographic diversity, illegal off-road vehicle use, groundwater withdrawal, and species compositions changes due to conversion of climax forest structure (New Jersey Department of Environmental Protection 2018).

The black bear population in New Jersey, initially concentrated in the northwestern Skylands region, has steadily spread south and east throughout the state since the 1980s, with bear now occupying all landscape regions and counties (New Jersey Division of Fish and Wildlife 2025).

Data Collection

We monitored underpass structures with Reconyx Hyperfire™ motion activated game cameras. Underpass sites were chosen for location either within or nearby habitat corridor areas, human access, and logistically feasible camera placement. We deployed at least two cameras at each site to monitor either side of the underpass and determine if a crossing occurred. We attached cameras to naturally occurring features when possible – primarily woody vegetation – and T-posts driven into the ground when not. Given the unique shape and topography of each site, and the need to stay above waterline, we placed cameras at various heights and angles to provide the best view of the underpass. We set the cameras to take bursts of give photos, with a one second delay between triggering events, and allowed them to run continuously. We checked cameras every 6-8 weeks to retrieve memory cards and check camera status. The data we used in this study was collected between July and early November of 2024.

Data Analysis

I developed Generalized Linear Mixed Models using the package lme4 in R (R Development Core Team 2010) with number of underpass use events as the dependent variable, a suite of habitat and infrastructure measurements as the independent variables, and roadway as a random effect. The independent variables, hereafter covariates, were selected to investigate how the infrastructure at each site and its surrounding habitat could impact black bear movement. They include NAACC terrestrial passage score for bear, proportion core habitat in the surrounding area, and distance to the nearest core habitat or corridor area. Each covariate is described in detail below. Given our limited sample size (37 sites) we limited our number of covariates to three. We used AIC to evaluate the null model (roadway only) and each potential combination of the three covariates (Burnham et al. 2010).

Terrestrial Passage Score

The NAACC terrestrial passage scoring system generates a crossing score between 0 and 1 for each species group at a given underpass using six variables, with a value of -1 representing an underpass with no data (North Atlantic Aquatic Connectivity Collaborative 2025b). These six variables include openness of the largest structure at a crossing (measured in meters and taking into account asymptote, midpoint, and steepness), height of structure (measured in feet, taking into account asymptote, midpoint, and steepness), length of structure (measured in feet, taking into account asymptote, midpoint, and steepness), whether or not there is a clear line of sight throughout the structure (no, partial, or yes), dry passage (no dry passage, inadequate dry passage, moderately useable dry passage, good dry passage, and excellent dry passage), and barriers to accessing crossing (total barrier, severe barrier, moderate barrier, minor barrier, and no barriers) (North Atlantic Aquatic Connectivity Collaborative 2025b). Most variables have different weightings of each parameters per animal grouping, except for dry passage and barriers to accessing crossing, which are evaluated the same across every animal grouping. Certain variables are also weighted differently for different animal groupings when creating the composite score. For animal grouping four, comprised of bear, coyote, cougar, and wolf, openness and clean line of sight are the heaviest weighted variables (North Atlantic Aquatic Connectivity Collaborative 2025b).

Nearby Core Area

Core habitat area was sourced from a public GIS layer provided by the New Jersey Department of Environmental Protection and created by the Connecting Habitat Across New Jersey (CHANJ) effort (New Jersey Department of Environmental Protection 2021). I used ArcGIS Pro to determine how much core area existed within a ten-kilometer radius of each underpass site, which approximates the average home range size of a female black bear in New Jersey (Fimbel 1990). Since it was impossible to sex all individuals from the camera data, this value also represents the average minimum home range size any bear might have, as male home ranges are several times larger than females (Fimbel 1990). I began by converting the core habitat layer into a 30m cell size binary raster with each pixel identified as either core habitat (1) or not (0). I then used the average function in the focal statistics tool, which is essentially a moving window analysis, to determine the proportion of core habitat pixels within a ten kilometer radius of each pixel included in the raster layer, creating a dataset that can be used to determine the proportion of core habitat within 10 km^2 of each 30m cell, throughout all of New Jersey and not just at each underpass site.

Distance to Nearest Core or Corridor Area

I used the Euclidean Distance tool within the Spatial Analyst toolbox in ArcGIS Pro applied to the same CHANJ core and corridor habitat data from the New Jersey Department of Environmental Protection (New Jersey Department of Environmental Protection 2021) to create a matching 30m cell size raster denoting at each pixel the distance to the nearest core or corridor area in meters. A value of zero for this variable indicates that the site is already within a core or corridor area, and a value other than zero is the distance in meters.

Bear Use

After all images were processed to identify those depicting black bear I then identified each unique bear event per site and roadway. An event was considered unique if no other bear images were captured within the previous 10 minutes, although changing this time to 5 minutes or 30 minutes did not change the outcome as most events were well spaced in time. Each event was evaluated to determine if a crossing likely occurred (e.g., pictures taken on both sides of culvert or pictures of bear obviously entering or exiting a culvert). The number of unique events per site is the measurement of bear use serving as the dependent variable in my regression model.

Model

I fit generalized linear mixed models using all potential combinations of my three covariates, as well as a random effect of roadway, to explain bear use per site. I applied a log link function based on the Poisson distribution of my dependent variable. I selected the model with the lowest AIC value as having the most support.

RESULTS

We captured 465,256 photos between last June and early November 2025 at our 37 underpass location. Of those photos, 10,073 contained black bear images, depicting 52 unique events. We observed bear events on Interstate 78, Interstate 80, and State Route 206 in the northwestern part of the state (Figure 2). Crossing events spanned nine sites with NAACC Scores ranging from 0 to 0.763, nearby core habitat proportions ranging from 0.017 to 0.93, and distances to nearest core or corridor areas ranging from 0 (found within a core habitat area) to 30 meters (Table 1).

One model, Bear Crossings ~ NAACC Score + Proportion of Core Habitat, from our candidate pool received support as best fitting our observed bear crossing data (Table 2). Both coefficients were significant, with NAACC Terrestrial Passage Score ($p < 0.001$) having a negative correlation with Bear Use, and Proportion of Core Habitat ($p = 0.045$) having a positive correlation with Bear Use (Figures 3 & 4). The random intercept, Roadway, had a variance of 2.459 and a standard deviation of 1.568, suggesting that there is variability across the population mean and that our use of Roadway as a blocking term was appropriate.

DISCUSSION

Both the NAACC Terrestrial Passage Score and proportion of core habitat within a ten-kilometer radius of each site were significant in describing the variance of black bear crossing events. The terrestrial passage score had a negative correlation with bear crossings while the proportion of core habitat had a positive correlation.

The Distance to Nearest Core or Corridor was not included in our selected model, and upon reflection we recognized a lack of variation, with all values being either 0 or 30 meters save for one outlier (Figure 3). This indicates all but one site were either within core habitat area or within one raster cell (30m) of a core or corridor area, which is likely due to the original site selection process identifying underpasses conducive to bobcat use. This variable may have had more correlation had the underpass sites been selected randomly.

The NAACC Terrestrial Passage Scores for black bears seeks to quantify how likely an underpass is to be used by a terrestrial species for crossing. This covariate had the strongest correlation with bear use, but in an unexpected direction. Under the assumption that this score is an accurate predictor for bear use, this covariate should have had a strong positive correlation with observed bear crossing events. The strong negative correlation seen in the regression analyses implies that passage scores for bear may not be fully representative of bear movement patterns and behavior and may not accurately predict which underpasses they will use. It may be beneficial to compare each set of six variables that make up the bear scores for each underpass site to the observed bear crossings in this study to determine which measurements are having such a strong negative correlation with bear use.

The proportion of core habitat within a ten-kilometer radius of each site had a positive correlation with bear use in every model. This suggests the amount of nearby core habitat area does influence bear movement through road heavy areas. This variable is not currently represented in the criteria considered for the NAACC scores (openness, height, length, clear line of sight, dry passage, and barriers to accessing crossing), which account for physical characteristics of the underpass itself. This is not to say that habitat qualities alone are better predictors of bear use, but rather that some combination of habitat information and underpass characteristics may provide a more encompassing predictive system.

The proportion of core habitat covariate having significance also provides some insight into how black bear move across urban areas. While black bear have been seen throughout all counties in New Jersey, it is possible they prioritize staying within and near core habitat areas, meaning bear will use underpasses close to or in the core habitat area they occupy as opposed to traveling further from that core habitat to find a larger or drier underpass.

Existing literature points to conflicting preferences for black bear underpass selection based on the underpasses themselves and the surrounding landscape and habitat features (Donaldson 2007). Inconsistencies about selection related to underpass dimensions are especially common, with some studies suggesting black bear prefer more constricted underpasses and others suggesting they prefer openness (Clevenger and Waltho 2005; Smith 2003). My own findings show habitat features may be more critical to underpass use than physical underpass properties, which could provide an explanation for the lack of agreement when underpass dimensions are considered the basis of selection.

For a species as secretive as the black bear (Scheick and McCown 2014), it makes sense that they tend to avoid human development when possible, even when their existence is deeply intertwined with an urban landscape. This does not serve to exclude increasingly frequent cases where bear are seen moving through and interacting with elements of human settlements, but perhaps suggests that further research needs to be done to determine if those cases exist out of choice or necessity on the bears' part. In a state like New Jersey with a human population nearing 10 million people and the highest density of humans (500/km^2) of any state in the nation, understanding the behavior of large predators, like the black bear, is critical to help mitigate potentially harmful human-wildlife interactions (World Population Review 2025). If black bear tend to stay within core habitat areas, preserving those areas is important to make sure both humans and bears have space to thrive separately in a state that is constantly growing and changing to accommodate its growing population.

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TABLES

Site	Road	NAACC Passage Score	Nearby Core Habitat	Nearest Core/Corridor	Crossings
Muddy Run	78	0.18	0.4	30	6
Turkey Hill Brook	78	0.76	0.43	30	2
Beaver Brook	80	0	0.63	30	5
Delawanna Creek	80	0.2	0.48	0	12
Dry Tunnel	80	0	0.93	0	8
Trout Brook	80	0.18	0.66	30	5
Little Flat Brook Trib	206	0	0.7	30	10
Lubbers Run Trib	206	0.06	0.58	0	3
Peapack Brook Trib (2)	206	0.56	0.02	0	1

Table 1. Underpass sites with observed bear road crossings from trail cameras in Northern New Jersey between July and November 2025. Number of bear crossings displayed for each underpass site along with corresponding North Atlantic Aquatic Connectivity Collaborative (NAACC) Bear Passage Score, proportion of Connecting Habitat Across New Jersey (CHANJ) core habitat within a 10 km^2 radius, and Distance to Nearest Core/Corridor Area in meters.

Model	K	AICc	Delta AICc	AICc Weight	Cumulative Weight
NACC + Proportion Core	3	136.8	137.52	0.57	0.57
NACC	2	139.3	139.65	0.20	0.77
NACC + Proportion Core + Habitat Distance	4	138.8	140.05	0.17	0.93
NACC + Habitat Distance	3	141.1	141.83	0.07	1
Proportion Core	2	173.7	174.05	<0.00	1
Proportion Core + Habitat Distance	3	175.2	175.93	<0.00	1
Null	1	176.3	176.41	<0.00	1
Habitat Distance	2	177.8	178.15	<0.00	1

Table 2. Candidate models evaluating bear road crossings using underpass structures in Northern New Jersey between July and November 2025. Model selection via AICc identified the North Atlantic Aquatic Connectivity Collaborative (NAACC) bear passage scores and the proportion of Connecting Habitat Across New Jersey Core Habitat within 10 km^2 radius (Proportion Core) as most supported to explain black bear crossing events.

FIGURES

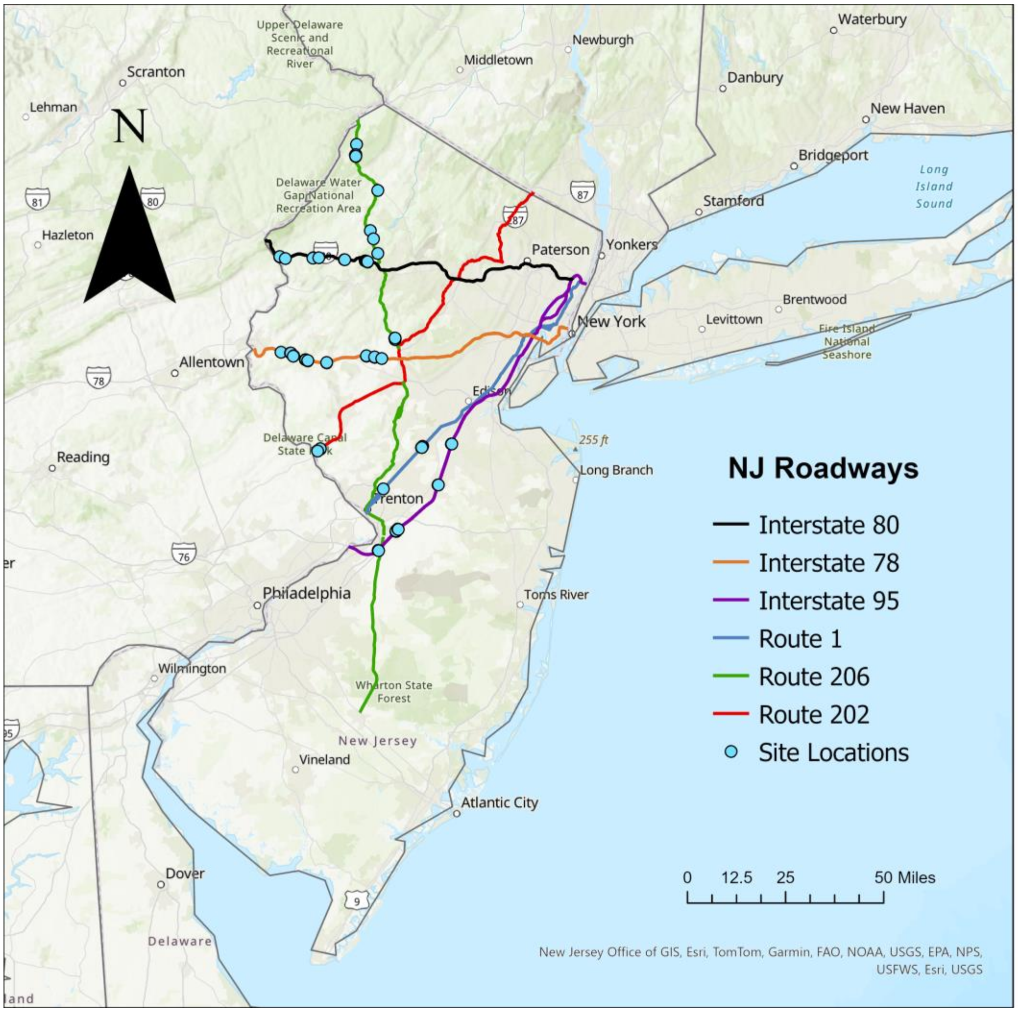

Figure 1. The locations of 37 underpasses (i.e. bridges and culverts) along six major New Jersey Roadways (State Route 1, Interstate 78, Interstate 80, Interstate 95, State Route 202, and State Route 206) monitored with remote cameras to identify wildlife crossing events between July and November 2024.

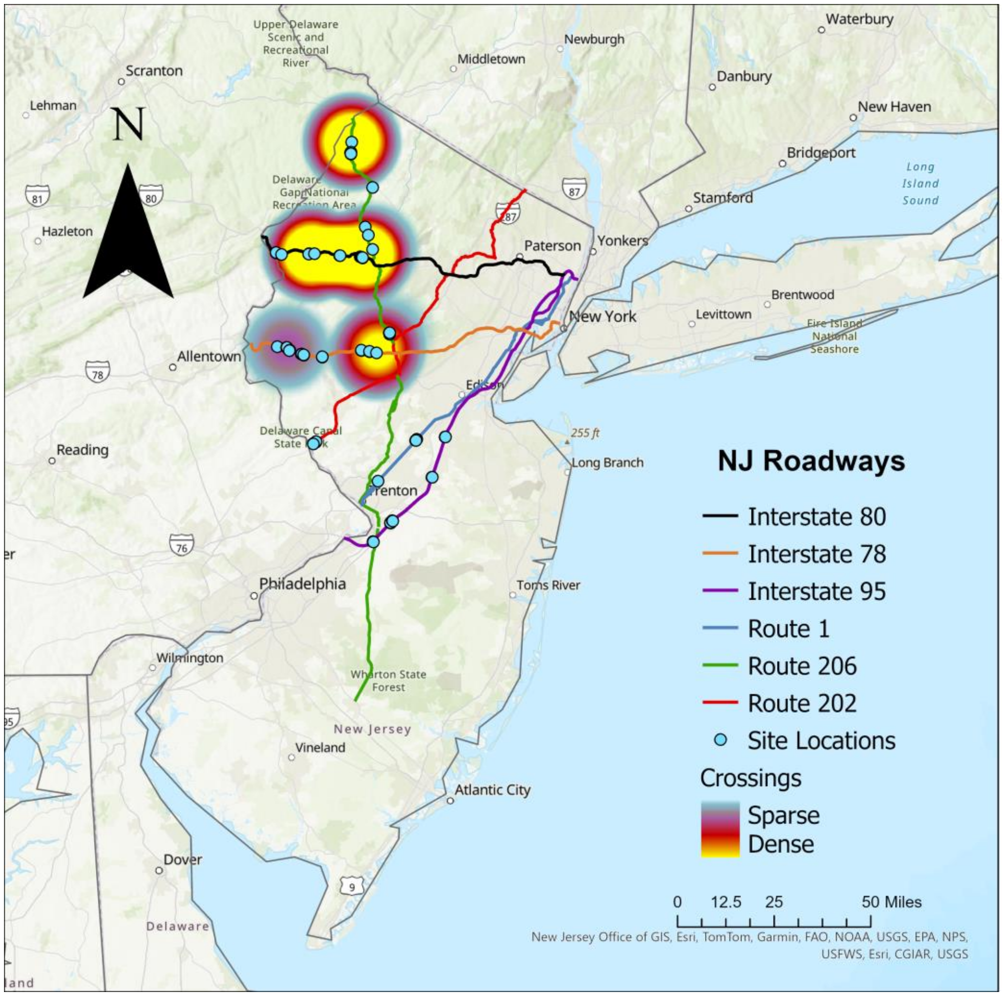

Figure 2. The locations of black bear crossing events along six major New Jersey roadways (State Route 1, Interstate 78, Interstate 80, Interstate 95, State Route 202, and State Route 206) observed with remote cameras between July and November 2024. Yellow to red areas indicate higher number of events, and purple to blue areas indicate a low number of events. This map shows the most observed black bear crossing events within the study period occurred on Interstate 80, followed by State Route 206 and Interstate 78.

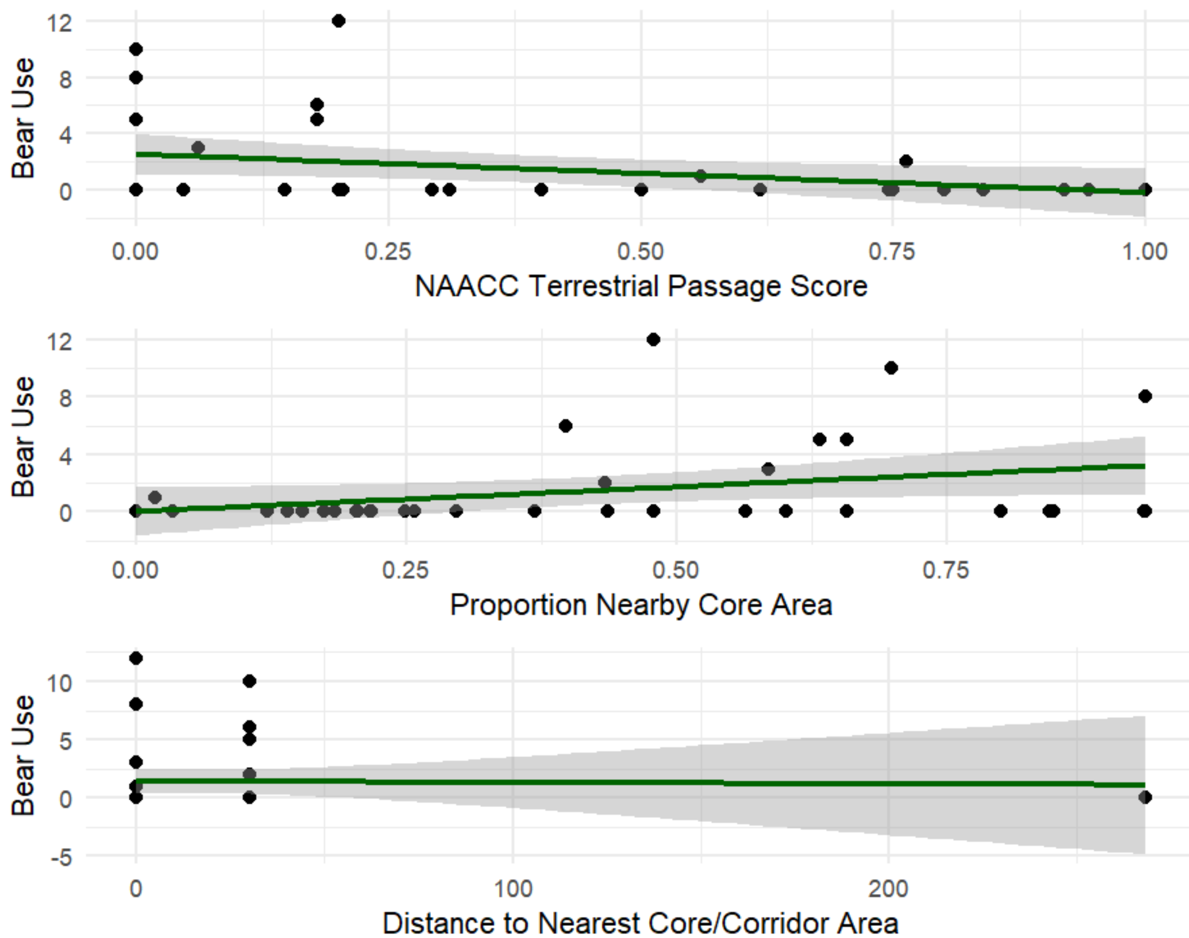

Figure 3. Regression lines created in RStudio showing the correlation between observed bear crossing events in Northern New Jersey between July and November 2024 with the three covariates used in this study: North Atlantic Aquatic Connectivity Collaborative (NAACC) bear passage score, proportion of Connecting Habitat Across New Jersey (CHANJ) core habitat within a 10 km^2 radius, and Distance to Nearest Core/Corridor Area in meters. These analyses show NAACC bear passage score having a negative correlation with bear crossing events, and proportion of CHANJ core habitat within a 10 km^2 radius having a positive correlation with bear crossing events.

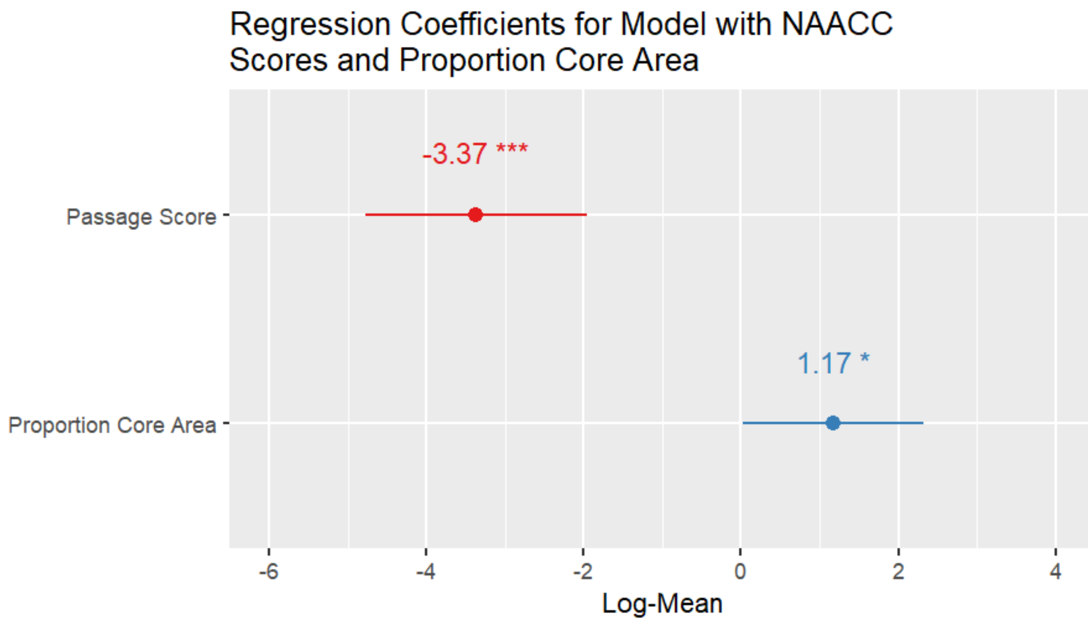

Figure 4. Regression coefficients and their 95% uncertainty intervals from a generalized linear mixed model assessing bear crossing events at underpass sites in Northern New Jersey between July and November 2024. Model selection using AICs identified the best fitting model using the North Atlantic Aquatic Connectivity Collaborative (NAACC) bear passage score and the proportion of Connecting Habitat Across New Jersey (CHANJ) core habitat within a 10 km^2 radius of each underpass site.