CHAPTER 2 – WILDLIFE POPULATIONS AND ROAD CORRIDOR INTERSECTIONS

INTRODUCTION

The massive 4-million-mile (6.2 million-km) system of public roads in the United States is used by more than 200 million vehicles every year. This engineering marvel, largely a product of the post-war economy, permeates and links nearly every urban and rural area in the country as illustrated in Figure 3. Together these paved roads constitute approximately one percent of the land area in the United States, roughly the size of Maine. Richard Forman (Harvard University) took this one percent figure one step further by placing roads in the environmental context in which they occur. Since the environmental impacts of roads extend well beyond their paved edge, he estimated that roads affect roughly 20 percent of the land area of the United States.

Figure 3. Photo. The highway system in the United States is used by more than 200 million vehicles and covers more than 6.2 million km (Credit: Tony Clevenger).

The North American economy and population are expected to grow considerably in the next 25 years. In the United States today, traffic and roads are strongly implicated in many of the major environmental problems: air and water pollution, heavy energy use, fragmented farmland and habitat, wildlife and biodiversity losses, and disruption of ecological communities. In turn, these problems can adversely affect human and ecosystem health and the nation's overall quality of life.

It comes as little surprise that the ecological effects of roads are gaining more attention among transportation agencies, land managers, local decision makers and the general public. Today road networks continue to expand and there are increasing public and political concerns regarding transport, ecology, quality of life, and local communities.
Understanding how roads affect their surrounding environment and wildlife populations will be important for planning and designing practical applications to properly mitigate their impacts.

THE NEW WEST

In much of the North American West, road networks are extensive and the volume of traffic on rural roads has sharply increased, as wild lands are progressively being developed and suburbanized. This new frontier phenomena results in vast changes in land use patterns and the alteration of natural habitats, leading to increased motorist–wildlife conflicts. In the East, the footprint of road systems is relatively stable compared to the growing New West phenomena. Nevertheless, traffic volumes in the East continue to rise on existing roads; suburban areas are expanding amidst a general trend of increasing deer populations.

THE ECOLOGY OF ROAD CORRIDORS

Historically, roads followed natural landscape contours and ran parallel and adjacent to rivers and streams. But post-war transportation planning and road building diverged from the sinuous, landscape form of roads and became more angular and rectilinear in order to provide efficient travel between population centers and key points of interest. As a result, today many roads and highways cut across landscapes, intersect ecosystems and impact local habitats. In doing so, terrestrial and aquatic flows such as wildlife movements and distributions, subsurface and surface hydrology and wind erosion may be blocked or altered. Roads have five different ecological functions that affect wildlife. Roads function as habitats, sources, sinks, barriers, and conduits. Depending on the road, its location and the number of vehicles traveling on it, some of these functions may have important ecological significance.

- As *habitats*, road corridors may harbor entire populations of plants and animals and may be of conservation importance. If they contain some of the last remaining native or semi-native habitats for a species they may be critically important.
- Road corridors may be *sources*, if wildlife populations thrive in these linear habitats compared to adjacent habitats.
- Road corridors where wildlife populations consistently experience high levels of mortality compared to populations in adjacent habitats are considered *sink populations*.
- When roads disrupt wildlife movements connecting habitats and populations, then road corridors are a *barrier*, blocking or selectively filtering important population movements and interchange of individuals and genes.
- The *conduit* or *corridor function* of road corridors occurs when wildlife move parallel along roads in corridor habitat, linking populations found in otherwise isolated patch habitats.

IMPACTS OF ROADS ON WILDLIFE POPULATIONS

Many studies have documented how roads affect wildlife populations and their ability to persist locally or even at a larger landscape scale. Some of the mechanisms for these impacts range from habitat loss and fragmentation to disrupting animal movement and road-related mortality. Mortality and habitat fragmentation are considered to be the greatest threat by far to maintaining wildlife populations. The many ways that roads alter wildlife habitats and the distribution of wildlife populations are described below.

Change In Habitat

Habitat Loss

Road construction and expansion result in loss of wildlife habitat by transforming natural habitats to pavement, dirt tracks, and cleared roadsides or right-of-ways. Some wildlife are more vulnerable to habitat loss than others. Wildlife that have large area needs, are found in relatively low densities, and have low reproductive rates tend to be the most sensitive to road-induced habitat loss. Wide-ranging carnivores are particularly vulnerable to road impacts for those reasons, and thresholds of road density for some carnivore species are known to limit their distributions. Similar patterns of road densities and population persistence have been documented for some amphibian populations in North America and Europe.

Road construction can increase the amount of edge habitat in a landscape conceptually shown in Figure 4. Because roads tend to be shaped long and thin, a disproportionately large amount of forest edge is created. This may benefit some edge-dwelling species, but can be detrimental to forest interior species as it may decrease in the amount of available habitat.

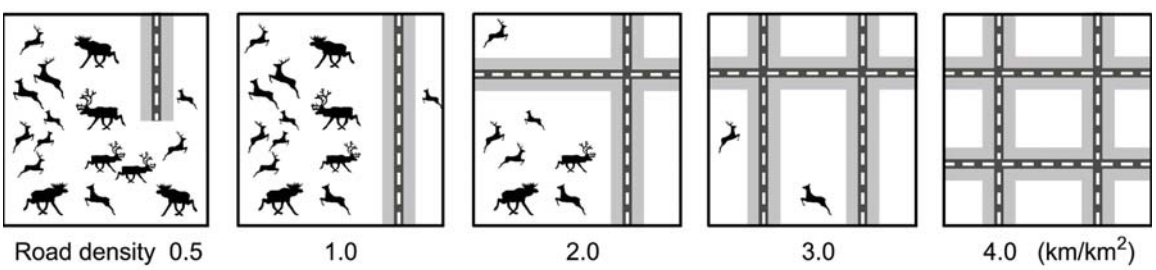

Figure 4. Schematic. Increasing road density fragments habitat into smaller patches and creates a disproportionate amount of edge habitat (from Iuell 2005).

Metapopulation theory suggests that the more mobile species are, the better they are able to manage with habitat loss. Yet mortality of individuals in the areas between the important core habitat patches (i.e., matrix habitat) usually does not figure into metapopulation theory as illustrated in Figure 5. Studies have shown that when mortality is high in the matrix habitat, highly mobile species are actually more vulnerable to habitat loss. Road corridors are one example of many possible matrix habitats in fragmented landscapes.

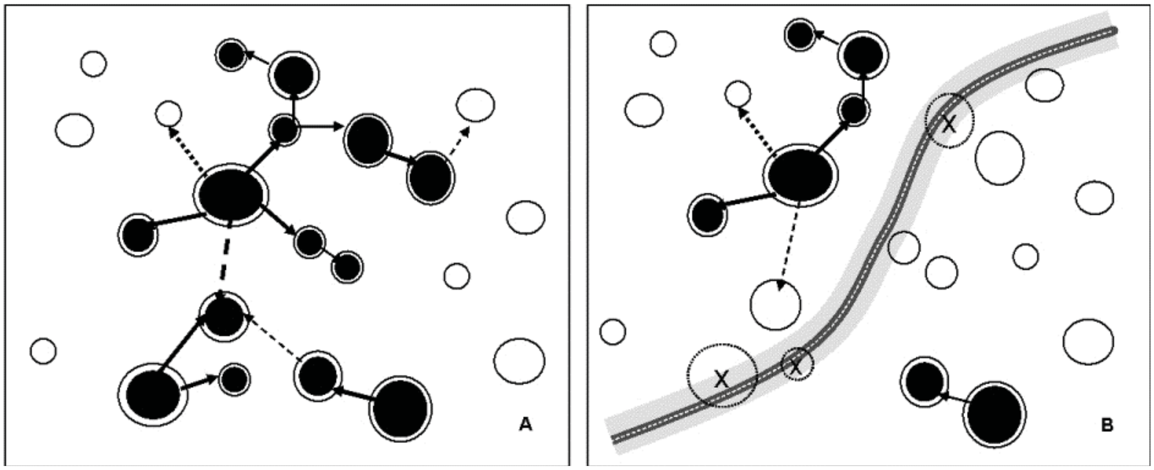

Figure 5. Schematic. Barrier effects on populations. (A) A metapopulation consists of a network of local subpopulations that may vary in size and local dynamics but are linked to each other through dispersal. (B) Road construction causes a disturbance and loss of local populations within the network. In addition, infrastructure imposes a barrier to dispersal that can prevent recolonisation and isolate local subpopulations from the rest of the metapopulation. If important source populations are cut off from the remaining sink populations, the entire metapopulation may be at risk of extinction (from Iuell 2005).

Diminished Habitat Quality

Disturbance from roads can affect wildlife behaviorally and numerically. Behavioral responses of wildlife typically consist of two types:

1. An avoidance response (zone of road avoidance) associated with regular or constant traffic disturbance, and
2. Avoidance due to irregular, less predictable isolated disturbances.

The numerical effect of roads on wildlife may be a decrease in population abundance or density of breeding individuals in habitats adjacent to roads. Should these distributions be strong enough to limit movements across roads, populations can become genetically isolated and the ability to persist over the long term becomes more precarious as graphed in Figure 6.

Improved Habitat Quality

Some wildlife (e.g., snakes) may be attracted to road corridors or the physical surface of roads for a variety of reasons as also shown in Figure 7, but most often the attraction is a result of conditions related to adjacent habitat (nesting, living space) or food found in the right-of-way.

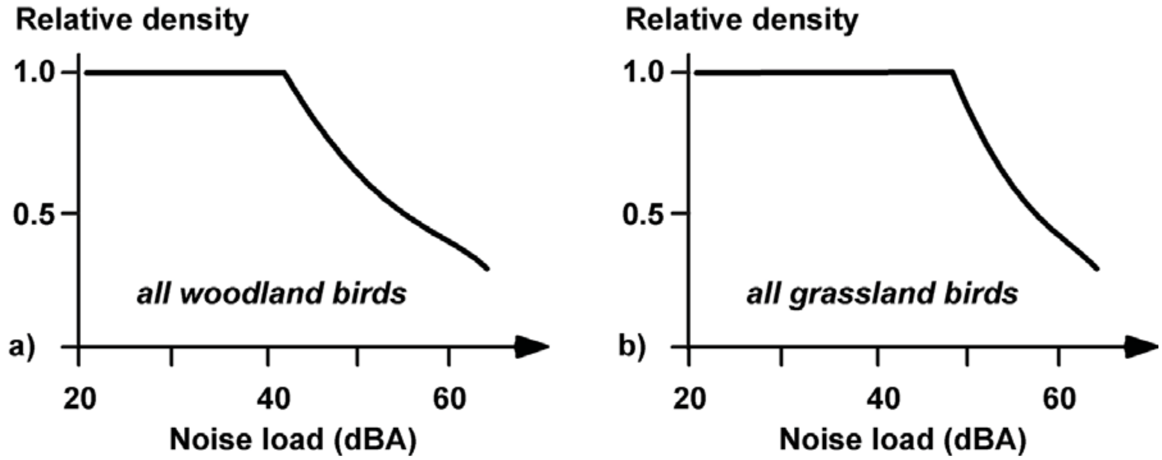

Figure 6. Graph. Results of studies on the impact of traffic noise on breeding bird populations in The Netherlands. When the noise load exceeds a threshold of between 40 and 50 dBA, bird densities were found to drop significantly. The sensitivity to noise and the threshold is different between species and between forested and open habitats (from Reijnen, Veenbaas and Foppen 1995).

Figure 7. Photo. Mountain goats attracted to roadside vegetation along Highway 93 South in Kootenay National Park, British Columbia, Canada (Credit: Tony Clevenger).

Road construction can create high quality habitat where food resources are more abundant compared to adjacent areas. When roads are fenced to keep wildlife out, lush forage along medians and right-of-ways is created and attracts herbivores, from Microtine Rodents to Deer and Elk. Locally abundant small mammal populations living in these fenced areas become targets for avian and terrestrial predators such as Owls, Hawks, Coyotes and Foxes.

When predators forage in the fenced road corridor close to traffic, collisions with vehicles are inevitable, thus making roadside carrion available and attracting aerial and terrestrial scavengers if not promptly removed by highway maintenance crews.

Change In Wildlife Distribution

Barrier Effects

Landscape connectivity is the degree to which the landscape facilitates animal movement and other ecological flows. High levels of landscape connectivity occur when the area between core habitats in the landscape comprise relatively benign types of habitats without barriers, thus allowing wildlife to move freely through them in meeting their biological needs.

Landscape connectivity is important for two reasons:

1. Many animals regularly move through the landscape to different habitats to meet their daily, seasonal and basic biological needs.
2. Connectivity allows areas to be recolonized, for dispersal, for maintaining regional metapopulations and minimizing risks of inbreeding within populations.

Reduced landscape connectivity and limited movements due to roads may result in higher wildlife mortality, lower reproduction rates, ultimately smaller populations and overall lower population viability. These harmful effects have underscored the need to maintain and restore essential movements of wildlife across roads to maintain within population movements and genetic interchange. This is particularly important on roads with high traffic volumes that can be complete barriers to movement.

The fragmentation effect of roads begins as animals become reluctant to move across roads to access mates or preferred habitats for food and cover. The degree of aversion to roads may vary by age group and gender. The reasons why roads are avoided can generally be attributed to features associated with the road, e.g., traffic volume, road width or major habitat alterations caused by the road.

High-volume and high-speed roads tend to be the greatest barriers and most effective in disrupting animal movements and population interchange. However, some studies have shown that secondary highways and unpaved roads can also impede animal movements.

Corridor Function

Roads can limit movement for some wildlife, but they can also facilitate dispersal and range extensions of others, native and non-native. Depending on the species and the surrounding landscape, the right-of-way can be important habitat and possibly the only remaining functional habitat for some species in highly developed landscapes as shown in Figure 8. Right-of-ways may also serve as travel corridors between patches of important wildlife habitat.

Figure 8. Photo. Right-of-ways can vary considerably between different landscapes and parts of North America. Left: A two-lane highway in Jasper National Park. Dense vegetation of plants, shrubs and trees along roads provide potential nesting sites for birds and screen the road and its traffic from the surrounding landscape. Right: Interstate-65 in Kentucky consisting of a wide right-of-way with little native vegetation. (Credits: Tony Clevenger).

Mortality

The total number of motor vehicle accidents with large wildlife each year has been estimated at one to two million in the United States and at 45,000 in Canada. These numbers have increased even more in the last decade. In the United States alone, these collisions were estimated to cause 211 human fatalities, 29,000 human injuries and over US$1 billion in property damage annually.

National trends were studied through reviewing several sources of crash data from the United States. From 1990 to 2004, the number of all reported motor vehicle crashes has been relatively steady at slightly above six million per year. By comparison, the number of reported wildlife–vehicle collisions over the same period has grown from less than 200,000 per year to a high of approximately 300,000 per year, a 50 percent increase. Looking at the data another way, wildlife–vehicle collisions now represent approximately 5 percent (or 1 in 20) of all reported motor vehicle collisions. The increase in wildlife-related accidents appears to be associated with an increase in "vehicle miles traveled" and increases in deer population size in most parts of the United States.

Traffic has been shown to be the leading mortality source for some wide-ranging mammals, e.g., Florida Panther, regional Bear and Bighorn Sheep populations. Roads were also shown to be the primary cause of wildlife population declines and habitat fragmentation among many amphibian populations.

ROAD-RELATED MORTALITY VS. BARRIER EFFECTS

Road-related mortality and reduced wildlife movements have the biggest effect on keeping wildlife populations viable over the long term. However, the degree to which these factors depress or threaten populations depends on the level of traffic volume. A conceptual model shown in Figure 9 describes the effect traffic volume has on (1) animal avoidance of roads, (2) the likelihood of them getting killed while trying to cross, and (3) successful crossing attempts.

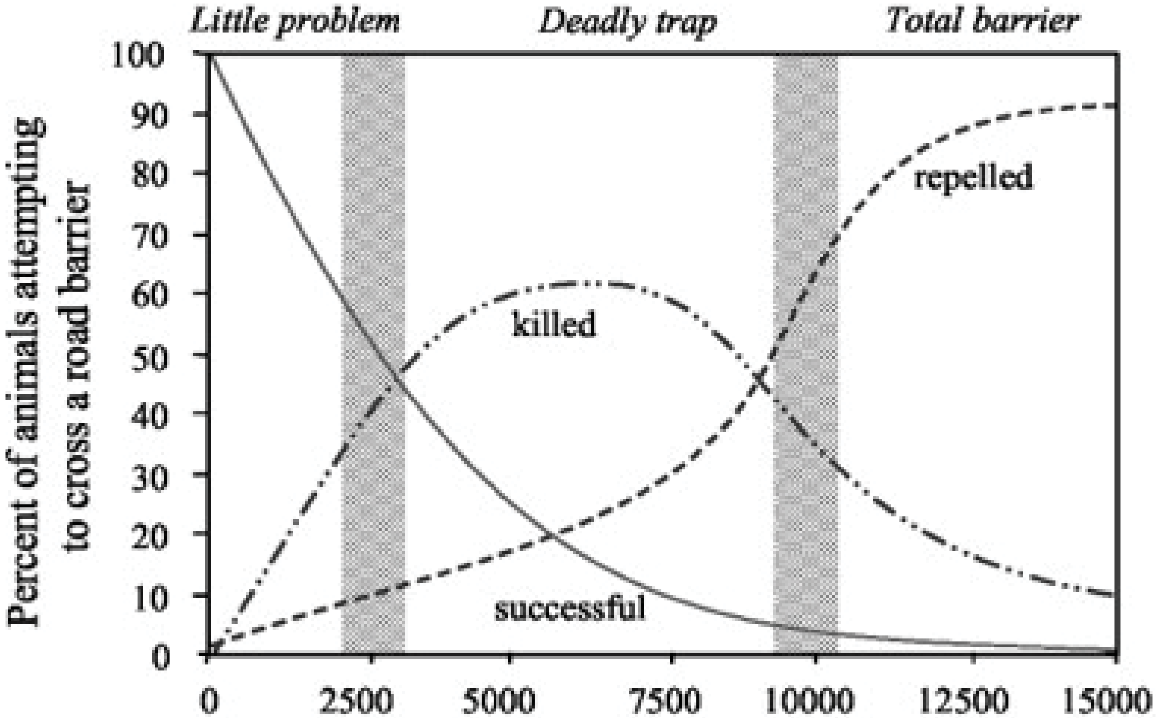

Figure 9. Graph. Conceptual model on the effect of traffic volume on the percentage of animals that successfully cross a road, are repelled by traffic noise and vehicle movement, or get killed as they attempt to cross. The conceptual model indicates that most collisions occur on intermediate roads (from Seiler 2003).

At low traffic volumes (<2500 annual average daily traffic volume (AADT)) the proportion of traffic-related mortalities is generally low, as is the number of animals that may be repelled by the road and traffic disturbance, thus having little or no impact on the population.

As traffic volumes increase to moderate levels (2500–10,000 AADT) mortalities are expected to be high, the number of animals repelled by roads will likely increase, and the proportion of successful crossings should start to decrease dramatically.

At high traffic volumes (>10,000 AADT), only a small proportion of attempted road crossings are expected to be successful. A large proportion of the animals approaching the road are likely repelled due to disturbance and heavy traffic volume, thus traffic-related mortality rarely occurs at all.

The model is particularly useful for understanding how wildlife mortality and cross-highway movements change with varying levels of traffic volume. Low rates of road-related mortality on a busy highway might be interpreted as evidence that impacts are negligible to wildlife, but in actuality the impacts may be that species have become locally extinct or that traffic disturbance effectively keeps them far from the highway surface. The thresholds and shape of the distribution in the model may be species-specific.

A THRESHOLD FOR TRAFFIC VOLUME AND ROAD EFFECTS?

There has been some thought towards exactly what is the threshold of traffic volume above which roads become a deadly trap, as the model[1] describes, and when there is an urgent need for management intervention. It is unclear whether 2000–3000 vehicles per day is a threshold for transportation agencies to be concerned about. How abundant species are, their behavior and their biological needs will strongly affect what the threshold levels are for different wildlife. Nevertheless, the model provides a basis for further examination of two-lane or low-volume road impacts on mortality and fragmentation of wildlife populations.

[1]Andreas Seiler, unpublished data.

Road-related mortality and barrier effects do not impact wildlife populations equally. The effects of road-related mortality on local populations may be seen in one or two generations, while loss of connectivity may take several generations to manifest.

Performance assessments of mitigation measures designed to reduce the impacts of road-related mortality and barrier effects should consider the combined performance of the measures in reducing those two impacts, rather than just one or the other.

Reducing road-related mortality and loss of individuals from populations generally has the greatest positive impact in maintaining populations locally. This is particularly true for medium- and large-sized mammals such as Bears, Cats, Wolves, given their tendency to occur in low densities, their slow rates of reproduction and long generation times.

The design and implementation of functional wildlife crossing structures should promote adequate interchange within the populations affected by roads, allow access to important resources, and ultimately enhance the viability of wildlife populations. However, scientifically understanding how much movement within the population is necessary, and what constitutes a barrier to connectivity, are difficult questions, especially for rare, elusive species such as Wolverine, Grizzly Bear or Lynx as captured in Figure 10. Future research using new methods such as non-invasive genetic sampling of hair or scats, satellite technology using global positioning system (GPS) transmitters, and spatially explicit population viability models may help answer some of these elusive management questions regarding roads, habitat fragmentation and population connectivity.

Figure 10. Photo. Lynx photographed using a wildlife overpass, as part of crossing structure monitoring along the Trans-Canada Highway in Banff National Park, Alberta. Long-term monitoring of the wildlife crossings in Banff has enabled the documentation of the crossings used by locally rare carnivores such as Lynx, and Wolverine (Credit: Tony Clevenger/WTI/Parks Canada).

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