Overview of Transportation Impacts on Wildlife Movement and Populations

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Abstract

As long linear features on the landscape, railways, roads and highways have impacts on wildlife and wildlife habitat that are disproportionate to the area of land that they occupy. In addition to impacts on habitat, highways and railways are sources of road mortality that threaten wildlife populations. Indirect effects on wildlife include reduced access to habitat due to road avoidance and human exploitation. Transportation infrastructure also undermines ecological processes through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics. A variety of techniques have been used to mitigate the impacts of transportation systems on wildlife movements with mixed success. To make progress on these issues wildlife biologists must: 1) recognize the potential long-term effects of highways and railways on wildlife populations and advocate more strongly for appropriate mitigation measures, 2) document the impacts of transportation infrastructure on wildlife populations, 3) conduct landscape analyses to identify "connectivity zones" and use these analyses to engage transportation planners earlier in the planning process, 4) enlist transportation engineers to help solve technical problems, and 5) design and conduct good monitoring studies to effectively evaluate various mitigation techniques.

Overview of Transportation Impacts on Wildlife Movement and Populations

Impacts of Highways and Railways on Wildlife

As long linear features on the landscape, railways, roads and highways have impacts on wildlife and wildlife habitat that are disproportionate to the area of land that they occupy. Roads and roadsides cover approximately one percent of the United States, yet it is estimated that 15-20 % of the land is directly affected by roads and vehicles (Forman and Deblinger, 1998; Forman, 2000). With their larger size and higher traffic volumes, highways represent a more serious threat to wildlife, affecting a wider range of wildlife species and presenting an almost impassable barrier for many species of reptiles, amphibians and small mammals.

Roads, highways and railways impact wildlife in a variety of ways.

Direct loss of habitat. Road and railway construction results in changes in the habitat value of the land. Those areas covered by pavement or rails and the travel lanes of dirt or gravel roads are greatly diminished as wildlife habitat. Verges and medians are often intensively managed, though some habitat value persists. Grassy areas associated with highway and roadway alignments represent habitat discontinuities in forested landscapes and may serve as conduits facilitating the spread of undesirable plants and animals (Seabrook and Dettmann, 1996; Parendes and Jones, 2000).

Degradation of habitat quality. Storm water discharges, alterations in stream hydrology, air emissions and exotic plants can degrade habitats ranging up to several hundred meters from railways and highways (for reviews see Transportation Research Board, 1997 and Trombulak and Frissell, 2000).

Habitat fragmentation. Roads, highways and railways dissect continuous habitat patches resulting in smaller patch sizes and higher edge to interior ratios. In forested habitats, edges associated with roads and highways are a source of nest predators and brood parasites that threaten many neotropical forest songbirds (Askins, Philbrick, & Sugeno, 1987; Askins, 1994; Rich, Dobkin, & Niles, 1994). The loss of interior habitat is of concern for edge-sensitive species and smaller overall patch sizes may result in the loss of area-sensitive wildlife.

Road avoidance. Some wildlife species avoid areas adjacent to highways due to noise and human activity associated with roads. Such road avoidance has been documented for black bears, *Ursus americanus* (Brody and Pelton, 1989), grizzly bears, *Ursus arctos* (McLellan and Shackleton, 1988), wolves, *Canis lupus* (Thurber, Peterson, Drummer, & Thomasma, 1994), bobcats, *Felis rufus* (Lovallo and Anderson, 1996), turkeys, *Meleagris gallopavo* (McDougal, Vaughan, & Bromley, 1991), and caribou, *Rangifer tarandus* (Klein, 1979). In the Netherlands, there is evidence that traffic noise disrupts avian communities in both forested and grassland habitats (Reijnen, Foppen, ter Braak, & Thissen, 1995; Reijnen, Foppen, & Meeuwsen, 1996).

Increased human exploitation. Roads and highways increase human access for hunting and poaching. This may reduce wildlife populations in areas adjacent to roads and highways and contributes to road avoidance (Thiel, 1985; McLellan and Shackleton, 1988).

Road mortality leading to loss of populations. When traffic volume is high, small roads can represent a significant source of mortality affecting populations of reptiles and amphibians (van Gelder, 1973; Langton, 1989; Bernardino and Dalrymple, 1992; Patla and Peterson, 1994; Rosen and Lowe, 1994; Fowle, 1996). As individual animals are killed trying to cross a highway or denied access to critical habitats, local populations will likely fail or be substantially reduced. In eastern Texas road mortality may have caused the loss of timber rattlesnake, *Crotalus horridus*, populations from areas of high road density (Rudolph, Burgdorf, Conner, & Dickson, 1998). Another study of the Angelina National Forest in eastern Texas suggested that populations of large snakes were reduced by 50% or more to a distance of 450 m from roads and concluded that populations of large snakes may be depressed across eastern Texas due to road mortality (Rudolph, Burgdorf, Conner, & Schaefer, 1999). In some cases road mortality has been identified as a important threat affecting endangered species/subspecies such as the Florida Panther, *Felis concolor coryi* (Maehr, Land, & Roelke, 1991), Old World badger, *Meles meles* (Zee, Wiertz, Ter Braak, & van Apeldoorn, 1992), and Iberian lynx, *Felis pardina* (Ferreras, Aldama, Beltran, & Delibes, 1992). The koala, *Phascolarctos cinereus*, population on Phillip Island, Australia, declined 20 % per year between 1984 and 1991 with road mortality listed as the largest cause of death (Fisher, 1991).

Disruption of social structure. Roads may have decreased survival rates and disrupted social organization for mountain pygmy possums, *Burramys parvus*, by prohibiting the dispersals of males after the mating season (Mansergh and Scotts, 1989). Studies in the area of Banff National Park in Canada indicate that adult female grizzly bears are much less likely to cross highways than males (Gibeau and Heuer, 1996).

Reduced access to vital habitats. As barriers to wildlife movement, railways and highways reduce access to vital habitats for a variety of wildlife species. Wide-ranging mammal species can lose access to important habitats when movements are restricted by highways. Critical habitats required by wildlife species can be separated on either side a highway, jeopardizing local populations. In Glacier National Park in Montana, mountain goats, *Oreamnos americanus*, must cross U.S. Highway 2 in order to access an important mineral lick (Singer and Doherty, 1985). Highways have disrupted migrations of ungulates between summer and winter ranges (Klein, 1971; Ward, Cupal, Goodwin, & Morris, 1976; Ford, 1980; Ward, 1982). By separating aquatic habitat and upland nesting habitat for turtles, or terrestrial habitat and aquatic breeding sites for amphibians, highways can have significant adverse impacts on local populations of those species (Jackson, 1996).

Population fragmentation and isolation. Railways and highways create barriers to movement that subdivide animal populations. Local population extinctions may occur due to stochastic genetic and demographic events, environmental variability and natural catastrophes (Shaffer, 1981). Population extinction is more likely to occur in smaller populations, such as those produced by habitat fragmentation (Shaffer, 1981; Shaffer and Samson, 1985). Studies have documented that several species of small mammals are reluctant to cross even relatively small roads (Oxley, Fenton, & Carmody, 1974; Mader, 1984; Swihart and Slade, 1984). DeMaynadier and Hunter (2000) found that salamanders were reluctant to cross forestry roads, with larger and more heavily trafficked roads having the largest impact on movement. The loss of intermediate habitat patches ("stepping stones") also may contribute to population fragmentation (Trombulak and Frissell, 2000). Smaller and more isolated populations are more vulnerable to genetic changes due to genetic drift and inbreeding depression. Fencing of the Trans Canada Highway has had a significant effect on the movements of grizzly bears and preliminary genetic findings suggest major fractionation of the landscape (Gibeau and Heuer, 1996). Reh and Seitz (1990) found remarkable genetic differences in one population of common frog, *Rana temporaria*, that was surrounded by roads, a highway and a railway.

<u>Disruption of processes that maintain regional populations</u>. The dispersal of individuals between populations has been shown, based on theoretical grounds (Leigh, 1981; Fahrig and Merriam, 1985; Hanski and Gilpin, 1991; Beier, 1993) and field studies (Gill, 1978; Corn and Fogleman, 1984; Breden, 1987; Berven and Grudzien, 1990; Sjogren, 1991), to be important for the maintenance of genetic viability within local populations, and for maintaining local and regional populations in the face of population extinctions. Dispersal among local populations is important for maintaining gene flow, supplementing small or declining populations, and re-colonizing local populations lost to extinction events. Effects of habitat fragmentation on metapopulation dynamics (Dodd, 1990; Beier, 1993; Gibbs, 1993; Blaustein, Wake, & Sousa, 1994; Fahrig and Merriam, 1994) and specifically, the impacts of roads and highways on local and regional populations (Mader, 1984; Andrews, 1990; Reh and Seitz, 1990; Patla and Peterson, 1994; Vos and Chardon, 1998) are important factors affecting the long-term persistence of populations. As barriers to animal dispersal, highways constitute an important long-term threat to the maintenance of healthy wildlife populations.

The combined effects of transportation infrastructure – habitat loss and degradation, habitat fragmentation, road mortality, and the restriction of animal movement across the landscape – are likely to have serious consequences for wildlife populations over time. Studies in Canada indicate a correlation between traffic intensity and lower densities of calling anurans (Fahrig, Pedlar, Pope, Taylor, & Wegner, 1995) and between the density of paved roads within 1-2 km of wetlands and the diversity of wildlife in those wetlands (Findlay and Houlahan, 1997; Findlay and Bourdages, 2000). Population level impacts are hard to document and may not be readily apparent until years or decades have passed (Findlay and Bourdages, 2000). Harder still is the assessment of long-term effects from the disruption of metapopulation dynamics and differential impacts of transportation infrastructure on animal movements. Wildlife species are not all affected to the same degree by the barrier effects of road, highways and railways. These habitat barriers may act as "filters" that stop some individuals and allow others to pass through. By "filtering out" different species, habitat barriers can have important impacts on species distribution across fragmented landscapes (Kozakiewicz, 1993).

For additional summaries of highway and railway effects on wildlife, including effects of habitat fragmentation, see Andrews (1990), Bennett (1991), De Santo and Smith (1993), and Trombulak and Frissell (2000).

Mitigating Impacts of Roads, Highways and Railways on Wildlife Movements

Many mitigation projects are primarily designed to facilitate movements of a single species or small group of similar species. Public safety, protection of big game, and the conservation of particular populations of wildlife (including rare or endangered species) are the primary motivating forces behind mitigation projects. Little attention is being paid to the role of highway mitigation in maintaining overall landscape connectivity in the U.S., although attempts to construct wildlife passage systems for a broad range of species are being tried in Europe (Canters, 1997) and Canada (Leeson, 1998).

In North America most mitigation projects are designed to facilitate the movements of large mammals. Most are designed for ungulates (Reed, Woodard, & Pojar, 1975; Ward et al., 1976; Ford, 1980; Singer and Doherty, 1985; Romin and Bissonette, 1996). Exceptions include underpasses for Florida panthers (Foster and Humphrey, 1995; Land & Lotz, 1996) and black bears (Roof & Wooding, 1996) in Florida; amphibian tunnels in Massachusetts (Jackson and Tyning, 1989; Jackson, 1996), New York (M. Fitzsimmons, pers comm.) and California (H.B. Shaffer, email post); a wall with passage structures for reptiles and amphibians in Florida (Evink, 1998); and a proposal for 13 crocodile, *Crocodylus acutus*, underpasses in the Florida Keys (Evink, 1996). Mitigation projects for two federally listed species, the Houston toad, *Bufo houstonensis*, (Jenkins, 1996) and Desert Tortoise, *Gopherus agassizii*, (Boarman and Sazaki, 1996) utilized existing drainage culverts rather than underpasses specifically designed to meet the particular needs of these species.

Tunnels have been used to help facilitate the movement of wildlife across roads and highways in Europe, Australia, Canada and the U.S. Evaluations of the effectiveness of tunnels indicate the need for careful design and placement, and that effectiveness is dependent on a number of variables, including: size, placement, noise levels, substrate, vegetative cover, moisture, temperature and light (Jackson and Griffin, 1998). More recently, overpass structures, also called ecoducts or green bridges, have been used to facilitate passage for a wide range of species (Berris, 1997; Keller and Pfister, 1997). These large overpass systems for wildlife appear to the most effective design for accommodating the needs of a broad range of wildlife species.

Current and Future Issues and Challenges

Much progress has been made in the past several years in understanding the impacts of transportation infrastructure on wildlife and developing techniques and approaches for mitigated those impacts. To continue making progress on these issues wildlife biologists will need to address the following challenges.

<u>Fostering Greater Appreciation of the Problems Caused by Highways and Railways</u>. One important challenge is getting people to understand the scope and complexity of transportation impacts on wildlife. Too often the issue is viewed as one of an incidental take of animals rather than as a threat to wildlife populations. We must seek to frame the issue not as concern for individual animals but rather that of maintaining the ecological integrity of natural systems intersected by railways and highways. The movement of animals through the landscape is one of many ecological processes that must be maintained in order to insure the integrity of ecosystems over time. The impacts of railways and highways do not simply occur at the time of construction

but accumulate over time as populations fail due to transportation impacts and pathways for re-colonization are precluded (Findlay and Bourdages, 2000). Appropriate planning and mitigation at the time of construction can go a long way in preventing long-term degradation of wildlife populations and the ecosystems in which wildlife are important components.

Documenting the Impacts of Transportation Infrastructure on Wildlife Populations. There is a growing body of research into the ways that roads, highways and railways impact wildlife movements and populations. However, the extent to which these features are affecting wildlife populations and undermining ecological processes is still largely unknown. Further research is needed on the long-terms effects of transportation infrastructure as well as the nature and extent of impacts for a broader range of wildlife species.

Landscape Analyses to Identify "Connectivity Zones". The most effective techniques for facilitating wildlife movement (overpasses, viaducts, and large underpasses) are also quite expensive. Therefore, it is generally not practical to make entire highways or railways permeable to wildlife movement. A practical strategy for mitigating transportation impacts on wildlife movement may dictate that comprehensive efforts utilizing expensive elements be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitats (Jackson and Griffin, 1998). These landscape analyses are common in Europe (see Canters, 1997) and there are some notable examples from North America (Wagner, Carey, & Lehmkuhl, 1998; Carr, Zwick, Hoctor, Harrell, Goethals, & Benedict, 1998; Smith, 1999; Hoctor, Carr, & Zwick, 2000). To the extent that these areas can be identified ahead of time, planning for new transportation infrastructure can more effectively focused on minimizing and mitigating impacts to these critical areas.

Enlisting Transportation Engineers to Help Solve Technical Problems. There still is much work to be done in designing wildlife crossing structures that are effective for facilitating animal passage and practical for use in transportation systems. Biologists need to establish the performance standards for such structures based on the characteristics and needs of wildlife. The assistance of transportation engineers is needed to provide technical solutions and approaches so that crossing structures more effectively meet the standards identified by biologists. An example of a problem in need of a technical solution is how best to provide a wet environment within crossing structures to facilitate amphibian use during migration. Given the incredible feats of engineering accomplished over the years by transportation engineers, collaborative partnerships between biologists and engineers should be able to find practical solutions to many technical problems related to animal passage.

Monitoring and Evaluation of Wildlife Crossing Structures. Monitoring studies that evaluate the effectiveness of wildlife crossing structures have provided valuable information that is now available for use in designing future mitigation. As new structures are built it is particularly important that these efforts be monitored and the lessons learned from these mitigation experiments shared with others.

Most attempts to evaluate the success or failure of wildlife crossing structures have focused on documenting wildlife use of structures. Use of tracking beds, cameras, and counters do provide information about animals that use the structures. Unfortunately, monitoring structure use provides little information on species or individuals that fail or refuse to use the structure. Radio-tracking and trapping studies provide less information about structure use, but are more useful for determining the extent to which railways and highways inhibit wildlife movement and the degree to which crossing structures are able to mitigate these effects. In order to fully assess the effectiveness of wildlife crossing structures it may be necessary to use a combination of techniques that will evaluate both structure use and the degree to which railway or highway effects on animal movement are mitigated.

Conclusion

There is good reason for concern that roads, highways and railways are having a profound affect on wildlife populations and ecosystems, especially if considered at the landscape scale and over long time frames. Although progress has been made in recognizing and addressing these impacts, many challenges persist. There is a need for a significantly different approach to transportation planning, one that recognizes the long-term ecological costs of roads, highways and railways, and takes seriously the need to mitigate these impacts.

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