A comparison of roads and rivers as barriers to animal movements: implications for roads in protected areas

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Introduction

The spatial and temporal distribution of resources is a fundamental determinant of animal movement across the landscape (Puth and Wilson 2001). Scientists have only recently realized that ecological systems are rarely closed, thus resource management has shifted from species-species and habitat-species issues to examining ecosystems as a whole. Terrestrial vertebrate movements vary depending on home range or territory size, body size, prey availability, migratory status and habitat requirements. For example, a single Gray Wolf (*Canis lupus*) is known to have covered 100,000 km^2 in four and a half years (Fritts 1983). Home range sizes of Wolverine (*Gulo gulo*) range from 100 to 900 km^2, where they can travel 30 to 40 km per day in search of prey (Banci 1994), and a male Grizzly Bear (*Ursus arctos*) home range in the Yellowstone National Park is recorded at 2,322 km^2.

With increasing anthropogenic pressures on the landscape resulting in habitat degradation and fragmentation, the persistence of wildlife populations is under threat. Towns, roads and fences are direct barriers to animal movement, whereas deforestation and agriculture alter animal movement indirectly due to increased exposure to predators or lack of cover. If we are to prevent population declines or species extinctions, we need to provide considerable amounts of intact habitat that function to support healthy populations. Historically, national parks were established for economic value as places of recreation and tourism, and to preserve "features of the greatest beauty" (*e.g.,* Banff National Park 1885, Glacier and Yoho National Parks 1888) (McNamee 2002). As protected areas have increasingly become the main refuge for many animals and plants while the surrounding areas are developed, efforts to implement conservation strategies have increased, and the essential role of national parks has shifted to maintaining the integrity of natural ecosystems (Parks Canada 1994). However, development has continued (albeit at a slower rate) inside park boundaries.

Natural features also impede animal movement, but the extent to which these features function as barriers depends on the surrounding habitat, species, and species range and mobility (Lima and Zollner 1996). However, some generalization can be made when comparing animal permeability of roads and natural features (St. Clair 2003). In this paper I discuss roads as impermeable or semipermeable barriers to animal movement (Figure 1), by comparing roads to a specific natural barrier, namely rivers.

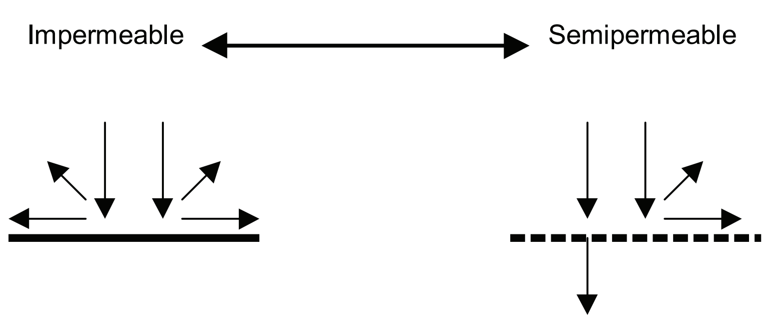

Figure 1. A permeability gradient exists in barriers such as roads and rivers, which is dependent on the organism studied, landscape type on either side of the barrier, width, and vulnerability to predation. Additionally, road permeability is a function of density, noise, volume of traffic, physical obstacles such as fences, and level of human activity.

Network of Roads

Roads have permeated nearly every environment on every continent (except Antarctica), in a vast network of cement, asphalt and gravel. In 2002, British Columbia had 64,500 km of highways and streets, and many times this number of forest service roads and recreation access roads (www.northwestwatch.org). It is well known that roads have a substantial effect on wildlife, including direct mortality (Barnes 1936, Allen and McCullough 1976, Rosen and Lowe 1994, Clevenger et al. 2003), spread of invasive exotics, increased erosion, air and water pollution, and habitat loss and fragmentation (Spellerberg 1998).

Roads also have severe effects on wildlife movement caused by the barrier that roads potentially create wherever they dissect habitat (Forman and Alexander 1998). The physical consequence of roads is the division of continuous habitat into a discontinuous one, which results in long linear gaps in the habitat that are hostile to many native fauna. This can divide populations into genetically distinct subpopulations because individuals are spatially separated, and therefore less likely to find each other during the breeding season. This results in a decrease in gene flow between the subpopulations, leading to increased inbreeding, which may ultimately affect population viability and persistence (Reh and Seitz 1990, Gerlach and Musolf 2000, Lode 2000).

Road density highly influences permeability of the landscape to animal movement, and Grizzly Bear, Black Bear (*Ursus americanus*; Figure 2), Canada Lynx (*Lynx canadensis*), Gray Wolf, and Caribou (*Rangifer tarandus*) all show avoidance of high road density areas in Canada and the United States (Mace et al. 1996, Dyer et al. 2002). A recent survey for the Yellowstone-to-Yukon (Y2Y) corridor plan calculated the road density required to support a Grizzly Bear population to be 0.30 km/km^2, and the current density of roads in the Y2Y ecoregion is 0.54 km/km^2 (Yellowstone to Yukon Conservation Initiative 2004). Road surface type may also influence permeability of some animals, for example, Bobcats (*Lynx rufus*) cross paved roads statistically less than expected, when compared with unpaved roads in Wisconsin (Lovalla and Anderson 1996).

Road avoidance can be gender-specific and temporally determined, depending on the species.

Figure 2. Black Bears generally avoid areas with high road density, but the quality and abundance of forage along some road edges often lures bears in search of an easy meal. Memekay River, BC. 27 June 2003 (Michael I. Preston).

During the calving season and late winter, female Caribou are easily disturbed and avoid crossing roads, more so than during the rest of the year (Wolfe et al. 2000, Dyer et al. 2002). This may be due to an increased risk of a predator attack on an exposed road, when their young are newborn, or during the advanced stages of pregnancy. Female Grizzly Bears also avoid roads more than males, especially in high-density or high-traffic areas (Mace et al. 1996).

Road width can influence permeability of roads to animal movement, though for some species, the more influential component of road width on road crossing decisions, is probably gap width relative to the surrounding habitat. For example, Canada Lynx will generally not cross large openings and often avoid crossing roads > 15 m wide (Defenders of Wildlife 2001), and for many forest songbirds the likelihood of flying through forest gaps decreases as gap width increases to about 200 m (St. Clair et al. 1998). Some forest birds are so sensitive that even narrow and seldom-used roads can result in a barrier to movement (Develey and Stouffer 2001).

Many animals do not perceive roads as barriers, and will willingly cross any that intercept their movement pathways (*e.g.,* snakes (Figure 3), songbirds, deer), but the vast number of animals that are killed on roads every year is evidence that roads are barriers even if animals do not perceive the risk of crossing them.

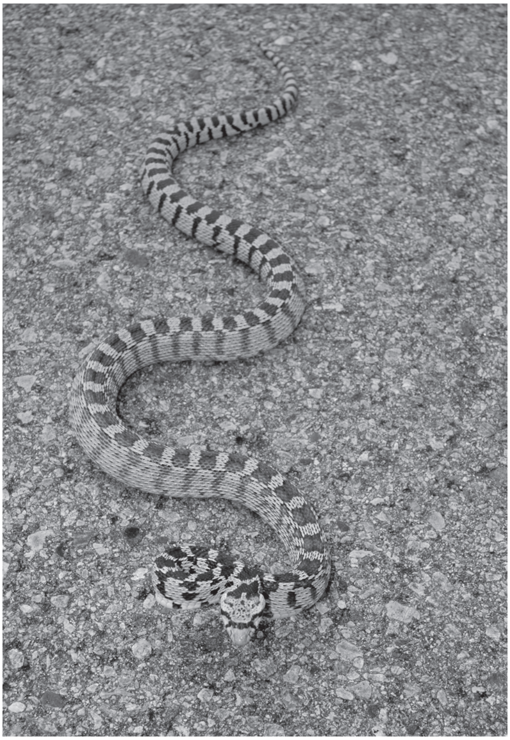

Figure 3. This Gopher Snake (*Pituophis catenifer*) was observed "sunning" in the middle of Inkaneep Road in the South Okanagan Valley, BC, where road mortality of snakes is a concern. 29 April 2006 (Michael I. Preston).

Comparing Roads with Rivers

There are many forms of natural barriers to animal movement, both terrestrial and aquatic, and it is only by understanding how these operate as inhibitory agents to dispersal and migration, do we appreciate the effects of artificial barriers on wildlife. One such natural barrier that exists worldwide is rivers. Examining barriers in the context of rivers offers several advantages when comparing them to roads. Rivers are easy to visualize as traditional barriers because they are linear (Puth and Wilson 2001), and divide the surrounding habitat in similar ways as roads. Also similar to roads, rivers come in many sizes, and the effects of width on animal movements can be quantitatively measured. The "riverine barrier hypothesis" had been accepted for several decades, and the concept of rivers as barriers was first proposed in 1852 by Alfred Russel Wallace from his observations of monkey populations in the Amazon (Wallace 1852). Since then, numerous researchers have accumulated evidence to support this hypothesis, and molecular data have revealed that separate subpopulations of many species exist on each side of rivers (Capparella 1991, Ayres and Clutton-Brock 1992, Peres et al. 1996, Patton 2000). Rivers are considered as semipermeable barriers because they do not separate all terrestrial species (Patton 2000). In Florida, Black Bears were reported to have crossed Caloosahatchee River, whereas Bobcats and Florida Panthers (*Puma concolor coryi*) did not (Maehr 1997). Rivers do not seem to inhibit movements of large carnivores such as Canada Lynx and Wolverine (Banci 1987, Aubry et al. 2000), and at times, Wolverines will use rivers as travel routes in pursuit of prey (Singleton et al. 2002). Many other animals such as Grizzly Bear, Moose (*Alces alces*), mustelids, canids, deer and Caribou frequently cross rivers either by wading or swimming (Figure 4). Therefore, compared to roads, many animals show little fear of rivers (*e.g.,* Wolverine), even though the natural gap in the habitat may expose animals to predators. Smaller mammals such as rodents and squirrels may find rivers more impermeable to movement due to their inability to swim across strong currents. Some forest songbirds such as

Figure 4. Most large mammals, such as this Moose, frequently cross rivers during day-to-day movements and annual migrations, suggesting that despite some risk, crossing these natural barriers is a part of life. Bow River, Jasper National Park, AB. 25 July 1991 (Michael I. Preston).

Black-capped Chickadee (*Poecile atricapillus*) and Red-eyed Vireo (*Vireo olivaceus*) generally avoid crossing gaps (Desrochers and Hannon 1997). Specifically, chickadees and kinglets are known to avoid river crossings (St. Clair 2003).

Similar to roads, rivers can restrict movement of animals according to season and gender. Many rivers are ephemeral or seasonably variable, which means that some rivers are more permeable at certain times of the year (Figure 5). In the Mississippi alluvial valley, Black Bears crossed rivers less during winter (*i.e.,* the rainy season) than any other season because of higher water levels (White et al. 2000). White et al. (2000) also observed that male Black Bears crossed rivers more frequently than females, which may be a reflection of female vulnerability to attack (possibly from conspecific males), or that perhaps rivers act more as territorial boundaries for females compared to males. In either case, female bears naturally avoid crossing rivers, which might suggest that they avoid crossing other gaps such as roads. Gender specific avoidance of roads has been observed in Grizzly Bears (Gibeau and Herrero 1998).

Rivers follow natural contours of valleys, especially in mountainous regions. In British Columbia there is a general northwest-southeast directionality of valleys, which parallel mountain ranges. Seasonal migratory animals such as Elk (*Cervus canadensis*) and Caribou utilize both valley bottoms and the high alpine, and specific migratory pathways are used each year. Many roads were built along the same valleys as rivers for convenience (*e.g.,* Highway 95 from Cranbrook to Golden), but many cross mountain ranges (*e.g.,* Highway 99 from Squamish to Cache Creek) that intercept the migratory pathways of some animals. For animals that depend on seasonal conditions for crossing wide rivers, or those that are not inhibited by rivers, the addition of an adjacent highway widens the gap, thus increasing the barrier effect.

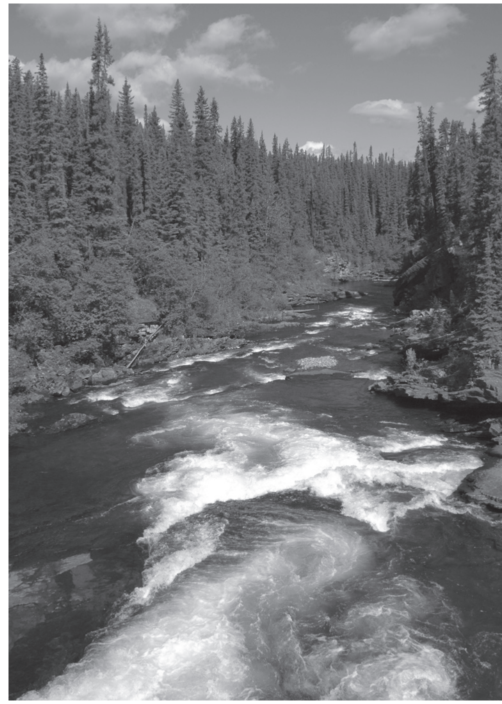

Figure 5. Seasonal fluctuations on some rivers may inhibit, or facilitate, animal crossings, depending on overall water volume, depth and velocity. Carbon Creek, BC. 22 June 2006 (Michael I. Preston).

Implications for Park Management

Kootenay National Park was established in 1922 on the condition that the British Columbia government was allowed to build Highway 93 through the Kootenay and Vermillion River valleys. In return, the province ceded 8 km on either side of the road to the federal government to be established as a national park. Over 80 years have passed since Kootenay National Park was established, and priorities have changed considerably in park protection and use, leading towards ecosystem-based management. The National Parks Act Amendments in 1988 indicate that the maintenance of ecological integrity is the first priority of Parks Canada, and this is to be regarded as ‘prerequisites against use’ (Parks Canada 1979). Parks Canada’s Guiding Principles for active management has stated that national park ecosystems must be managed with minimal interference to natural processes (Parks Canada 1994). Yet construction of public roads has continued inside park boundaries, and often, with the support of Parks Canada. It is often left to environmental groups, who have little funding for research, to prevent road proposals from coming to fruition. For example, Earthroots took the Ontario government to court in 2003 to prevent a logging road from being built through Bob Lake Conservation Reserve. Furthermore, the Canadian Parks and Wilderness Society (CPAWS) appealed to the courts to halt construction of a 118 km stretch of road through Wood Buffalo National Park that Parks Canada had approved in 2003.

Scientific evidence suggests road permeability to animal movement is highly influenced by road width. Therefore, width of highways should be minimized where possible, but especially in national parks so as to conform with the National Parks Act Amendments of 1988. Where road-widening projects do occur in national parks, extensive planning for wildlife mitigation must be met before receiving Parks Canada approval (*e.g.,* Banff National Park 2005-2008 project; Figure 6).

The ideal national park would have no roads at all, and future park locations should be considered on the basis of a long-term roadless area. In the United States, the USDA Forest Service adopted the Roadless Area Conservation Rule in 2001, to protect areas totaling 58.5 million acres (DellaSala and Strittholt 2003). These areas have been described as the last remaining intact and functional ecosystems of the United States. Many unused roads within parks such as Point Pelee National Park, are being deactivated so that they can revert back to their natural state, but countering this, new roads are also being upgraded and lengthened to enhance visitor use (Dearden and Rollins 2002). An accumulating body of literature show positive evidence of significant detrimental effects of roads on wildlife and the environment, therefore it is imperative that future parks are kept road-free.

Figure 6. Road-widening of Highway 1 in Banff National Park, AB, includes plans for wildlife mitigation. Near Lake Louise, AB. 29 October 2005 (Joanna Preston).

New Directions

One strategy for reducing road-related wildlife mortality, and facilitating wildlife movement, is the construction of wildlife overpasses (Figure 7) and tunnels. There is a growing body of literature and research investigating the efficacy of these structures. For some species, preliminary results seem promising for local movements and well-established movement corridors. However, animal movement is more widespread than what current bridges and tunnels can sustain.

Figure 7. Wildlife overpasses facilitate animal movement and greatly reduce the risk of collision with vehicles. Highway 1 in Banff National Park, AB. 29 October 2005 (Joanna Preston).

Roads often come with other physical barriers such as fences along the roadsides and concrete blocks separating oncoming traffic. Fences are often put up in national parks along roads to keep animals off the roads. However if an animal gets onto the road, they often cannot escape. For road-tolerant animals such as deer, raccoons, skunks, and snakes, these barriers can be the ultimate cause of mortality because they prevent the animal from getting safely to the other side, resulting in panic and an increased chance of being hit by a vehicle. Some mitigation measures that should be encouraged in British Columbia are one-way gates in fences to prevent ungulates on the road side of the fence from being trapped on the right-of-way (such as those erected at Coquihalla Lakes). Commonly, a continuous line of concrete blocks measuring only 2.5 ft. tall, and separating opposing lanes of traffic, may not seem like a barrier to animals. But rodents, frogs, reptiles, and other small mammals often cannot climb over them effectively, thus increasing their risk of a vehicle collision (Figure 8). Arch-shaped cement blocks (*i.e.,* a Jersey barrier with “wildlife scupper”) with room for small animals to crawl or slither through may alleviate this problem without reducing human road-safety (Figure 9).

Roads will always be a part of the landscape and it is our responsibility to reduce their negative impacts on wildlife and the environment. There is a growing body of research on reducing these impacts, and recent mitigation efforts to faciliate safe and effective animal movements are proving successful in some areas. However, more work is needed in testing the effectiveness of wildlife passages in the context of expected movement animal rates (Forman 2003). For those species that are strongly road-intolerant (*e.g.,* Wolverine), other creative options must be considered (*e.g.,* re-routing, tunnelling, road deactivating, and avoiding new road construction altogether).

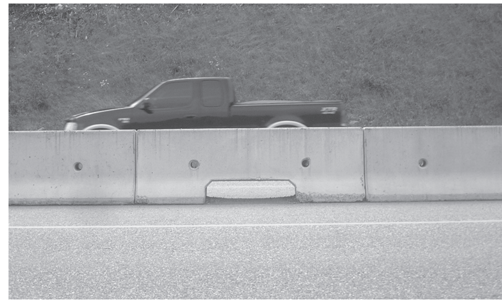

Figure 9. By constructing cement barriers with archways, small animals can cross roads with reduced risk and panic by having an unimpeded view of where they are going. Kootenay National Park, BC. (Larry Halverson).

Figure 8. Cement barriers that divide roadways effectively reduce crossing ability for many animals, including those that can easily jump over them such as this Eastern Gray Squirrel (*Sciurus carolinensis*). Sidney, BC. 15 January 2006 (Michael I. Preston).

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Joanna's interests in biology are widespread, but her passion is toward the conservation and protection of natural systems. Part of her spare time is spent volunteering for the Capital Regional District at the Witty's Lagoon nature centre in Metchosin.