# The Effect of Roads and Human Action on Roads on Grizzly Bears and their Habitat

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The following reviews the literature on the effects of roads and human action on roads on grizzly bears or their habitat. This review includes literature from throughout grizzly bear range in western North America regardless of jurisdiction and relative level of protection for bears.

Throughout North America human access to and negative action within grizzly bear range is the main reason for declines in grizzly bear populations (McLellan 1990, Schoen 1990, Banci et al. 1994, Mattson and Merrill 2002). Transportation and service corridors, particularly roads, are currently the primary form of human access to grizzly bear range. Roads and their associated ROWs, as well as human activity associated with roads, have a range of direct and indirect impacts on grizzly bears and their habitat (Table 1).

**Table 1.** The potential effects of roads and human action on roads on grizzly bears or their habitat.

| Effect |
|---|
| Increased risk of mortality |
| Exposure to anthropogenic foods |
| Change in bear behaviour |
| Habitat loss |
| Habitat alteration |
| Habitat displacement |
| Habitat fragmentation |
| Population fragmentation |

The physical surface of roads and habitat alteration of the ROW can affect grizzly bears positively or negatively. However, human action on roads rarely is beneficial to bears as it may change bear behaviour (McLellan and Shackleton 1989b, Northrup et al. 2012, Schwartz et al. 2010a) but, most importantly, often increases a bear's risk of human-caused mortality. Consequently, human action on roads can negatively impact grizzly bear survival to reproduce (Mace et al. 1996, Wakkinen and Kasworm 1997, Proctor et al. 2008, Boulanger et al. 2013) and, ultimately, population productivity (Schwartz et al. 2010, Boulanger and Stenhouse 2014). However, the actual magnitude of effect of roads on grizzly bears varies among different ecosystems as a result of a number of human and bear-related reasons (Table 2).

**Table 2. Influences on the magnitude of effect of roads and human action on roads on grizzly bears or their habitat.**

| Human-related influences | References |
|---|---|
| Variation in road density | Mace et al. 1996, 1999; Apps et al. 2004; Johnson et al. 2004; Schwartz et al. 2010; Graves et al. 2011; Boulanger et al. 2013, Boulanger and Stenhouse 2014 |
| Variation in the placement of roads and association to bear habitat, whether natural habitat or human-made (e.g., clearcuts, well sites) | Mace et al. 1996, Noss et al. 1996, Roever et al. 2008a & b, Boulanger et al. 2013, McLellan In review |
| Variation in the width of a road and ROW | Chruszcz et al. 2003, Graves et al. 2006, Graham et al. 2010 |
| Variation in the volume or pattern of vehicle traffic on roads | Archibald et al. 1987, McLellan & Shackleton 1988; Mace et al. 1996; Gibeau et al. 2002; Chruszcz et al. 2003; Waller & Servheen 2005; Ciarniello et al. 2007a; Roever et al. 2008b, 2010; Northrup 2010; Northrup et al. 2012 |
| Temporal (daily or seasonal) variation in human activity | Archibald et al. 1987, McLellan & Shackleton 1988, Gibeau et al. 2002, Mueller et al. 2004, Waller & Servheen 2005, Graves et al. 2006, Ciarniello et al. 2007a, Northrup 2010, Schwartz et al. 2010a, Northrup et al. 2012 |
| Variation in the type of human activity on roads and the probability a human will kill a bear during an encounter | Mattson et al. 1996, Wielgus et al. 2002, Johnson et al. 2004, Ciarniello et al. 2007a, Schwartz et al. 2010b |
| Variation in the availability of anthropogenic food to bears along a road | Mace et al. 1996 |
| Variation in jurisdictional management, including level of road closure | Benn 1998, Benn & Herrero 2002, Wielgus et al. 2002, Johnson et al. 2004, Nielsen et al. 2004b, Haroldson et al. 2006, Schwartz et al. 2010b |
| **Bear-related influences** | **References** |
| An individual bear's past experience with humans, including its tolerance of or habituation to human activity | Mattson et al. 1992, Gibeau et al. 2002, Chruszcz et al. 2003, Mueller et al. 2004 |
| Age or sex class of a bear, sometimes in relation to dominance status | Mattson et al. 1987, McLellan & Shackleton 1988, Wielgus and Bunnell 1994b, Gibeau et al. 2002, Chruszcz et al. 2003, Mueller et al. 2004, Graham et al. 2010, Northrup 2010, Schwartz et al. 2010a, Boulanger and Stenhouse 2014 |
| Variation in bear home range size, particularly relative to roads | Nielsen et al. 2004b |
| Temporal variation in bear activity pattern | McLellan & Shackleton 1988, Gibeau et al. 2002, Mueller et al. 2004, Graves et al. 2006, Graham et al. 2010, Northrup et al. 2012, Schwartz et al. 2010a |
| Seasonal or yearly change in the spatial distribution of a bear's preferred habitat or food | Mattson et al. 1987, 1992; Mace et al. 1999; Chruszcz et al. 2003; Roever et al. 2008a&b; Graham et al. 2010; Northrup 2010; Schwartz et al. 2010b |
| Relative quality of food resources near versus away from roads | Mattson et al. 1992, Gibeau et al. 2002, Nielsen et al. 2006, Roever et al. 2008a&b, Boulanger et al. 2013, McLellan In review |
| Distance to and amount of security cover for a bear | McLellan & Shackleton 1989, Gibeau et al. 2002 |
| Density of bears near versus away from roads | Ciarniello et al. 2009, McLellan In review |
| Competition or resource partitioning with sympatric black bears | Mattson et al. 2005, Apps et al. 2006, Schwartz et al. 2010a |

The majority of human-caused mortality of grizzly bears occurs near roads or human occupied areas (Knight et al. 1988, McLellan 1990, Mattson et al. 1992, Benn 1998, Benn and Herrero 2002, Nielsen et al. 2004b, Schwartz et al. 2010b, Boulanger and Stenhouse 2014, McLellan In review). Typically, grizzly bear mortalities increase near roads because of increased interactions with humans, especially where roads co-occur with quality grizzly bear habitat (Benn 1998, Johnson et al. 2004, Nielsen et al. 2004b, Boulanger and Stenhouse 2014). Bears die at a disproportionate rate when they are close to active roads and people who use the roads are armed (Mattson et al. 1996, Johnson et al. 2004, Ciarniello et al. 2007, Schwartz et al. 2010b, McLellan In review). In the absence of grizzly bear hunting, mortality can still occur from mistaken identity kills, self-defence kills, illegal kills (poaching), and malicious kills (McLellan et al. 1999). Most management control kills and landowner defense-of-life and property (DLP) kills also are near transportation corridors. In addition, grizzly bear deaths can occur from vehicle or train collisions (Gunther et al. 1998, Bertch and Gibeau 2009).

Benn (1998) found 85% of mortalities in the Central Rockies ecosystem of Alberta and British Columbia occurred within 500 m of roads and front country developments and 200 m around trails and backcountry developments. This proportion increased to 100% when only Banff and Yoho National Parks were considered (Benn and Herrero 2002).

Nielsen et al. (2004a) found that while grizzly bears made use of cutting units and associated habitats with roads in the foothills of Alberta, these bears experienced a higher mortality risk (Nielsen et al. 2004b). Nielsen et al. (2004b) found grizzly bear mortality was positively associated with human access, water, and edge features. Human access features were motorized and non-motorized roads or trails. In addition to grizzly bears selecting edge habitats and riparian areas, Nielsen et al. (2004b) suspected humans were more likely to be in those areas as well.

McLellan (in review) found that of the 31 bears that died while radio-collared over a 32 year study period in the Flathead River valley of southeast B.C., 26 (84%) were killed by people of which 11 (35%) were legally killed by hunters; 84% of human-caused deaths were < 120 m of a road.

In the U.S.-Canada trans-border Purcell-Yahk, South Selkirk, and Cabinet Mountain ecosystems, 76% of known-location human-caused mortalities occurred within 500 m of an open road (Wakkinen and Kasworm 2004). About 28% of identified non-hunting grizzly bear mortalities in the Purcell-Yahk and South Selkirk ecosystem sub-populations between 2003 and 2012 were a result of self-defence, mistaken identity, and illegal kills. Most of these mortalities occurred in back-country areas (MacHutchon and Proctor 2015). Roads are the main way that humans access the back-country in these sub-populations, so without roads most of these back-country mortalities would not have occurred. Several mistaken identity and self-defence kills were by ungulate or black bear hound hunters. Schwartz et al. (2010b) suggested that grizzly bear mortality associated with ungulate or black bear hunting could be easily absorbed by populations living in habitat fostering high survival (source areas) but could result in a sink effect if the addition of this type of mortality resulted in a non-sustainable rate of survival.

Vehicle traffic on roads and trails can alter bear behaviour. Some bears become more night active in response to vehicle traffic (Northrup et al. 2012, Schwartz et al. 2010a). This may not be their preference, but provides opportunity to feed along a road ROW or cross a road during a lower level of human activity. Some bears will habituate to or simply tolerate human activity on roads to get access to a food resource (Herrero et al. 2005, Haroldson and Gunther 2013). This can be beneficial to bears if it reduces the time and energy costs associated with a flight response to people (McLellan and Shackleton 1989, Gunther 1990, Herrero et al. 2005) and sometimes it can provide security from more dominant bears that are less likely to tolerate human activity (Schwartz et al. 2010a). However, grizzly bears active close to roads usually have a higher risk of human-caused mortality (Johnson et al. 2004, Nielsen et al. 2004b, Graham et al. 2010, Schwartz et al. 2010b, Boulanger and Stenhouse In review).

Gunther et al. (1998) analyzed the frequency of road killed wildlife, including grizzly bears and black bears, within Yellowstone National Park in relation to adjacent roadside cover types, posted speed limits, and average speed of vehicles. They found that speed of vehicles was the primary factor contributing to vehicle-wildlife collisions and that road design appeared to influence vehicle speed more than the posted speed limit.

Habitat is lost under the surface of a road or rail bed, which can result in a loss of foraging habitat, particularly in high quality habitats. Travel can be easier on a road, however this also increases a bear's vulnerability to human-caused mortality.

Habitat alteration along a road ROW can be a positive or negative change in habitat suitability for grizzly bears. Grizzly bear plant food availability often increases along a ROW because of (a) natural regeneration of native forbs and fruit-bearing shrubs in clearings or at the edge of clearings, (b) the deliberate seeding or inadvertent spread of desirable non-native plants, such as clover, common dandelion, and a variety of grasses, (c) an increased supply of nutrients or water, and (d) vehicle-killed carrion (Nagy and Russell 1978, MacHutchon and Mahon 2003, Roever et al. 2008a). In addition, as with a road or rail bed surface, grizzly bear travel can be easier along a ROW. However, foraging or traveling on a ROW increases a bear's risk of mortality particularly if the corridor is a road or a service corridor with an off-road vehicle trail (Nielsen et al. 2004b, Roever et al. 2008a, Boulanger et al. 2013). In some cases, habitat suitability may decline on ROWs if vegetative hiding cover is removed or clearing changes the habitat from a productive to a less productive seral stage.

Human activity on roads and highways can (a) disrupt individual grizzly bear foraging events, (b) cause some bears to temporarily move to less productive habitats, or (c) permanently displace some bears (Archibald et al. 1987, Mattson et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et al. 1996). The temporal and spatial degree of displacement of grizzly bears depends on many of the same factors that influence the magnitude of effect of roads listed in Table 2 (McLellan 1990, Schwartz et al. 2010a). Not surprisingly, the reported spatial displacement effect of roads and human action on roads ranges from habitat use less than expected within 100 m of a road (McLellan and Shackleton 1988) to disruptions of foraging up to 4 km away from a road (Mattson et al. 1987). Displacement of some age/ sex classes of bears may allow other bears more opportunity to feed along a road ROW, particularly if they tolerate road traffic. However, bears that become tolerant of or habituate to human activity on roads often have a higher risk of mortality.

Grizzly bear habitat can be fragmented by a high density of roads. Vehicle traffic and human activity on roads or trails may influence bears strongly enough to make some habitat fragments unavailable or no longer effective habitat for bears (i.e., loss of habitat security; Gibeau et al. 2001). In some cases, roads and ROWs can act as a barrier to movement because of (a) removal of vegetative security cover, (b) human behaviour on roads, or (c) traffic volume, timing, and pattern.

Although grizzly bears survive and reproduce in habitats with roads, it has been shown that survival decreases and avoidance of habitat near open motorized roads and trails increases with increasing road density (Kasworm and Manley 1990, Mace et al. 1996, Apps et al. 2004, Schwartz et al. 2010b, Boulanger et al. 2013, Boulanger and Stenhouse 2014). Because human action on roads can affect grizzly bear survival, the amount of road-less habitat in an ecosystem is frequently considered a measure of habitat security for grizzly bears (Gibeau et al. 2001, Proctor et al. 2008, Schwartz et al. 2010b).

Human use of roads is difficult to measure, so open road density is often used as an indirect measure of the amount of human use outside of secure habitat. Road density has been shown to be a good predictor of grizzly bear survival, particularly female survival (more roads, lower survival) and the proportion of core habitat (secure habitat) within a home range can be positively associated with higher survival (more core habitat, higher survival; Mace et al. 1996, Schwartz et al. 2010b, Boulanger and Stenhouse 2014). Schwartz et al. (2010b) considered core areas to be those which had no motorized and no high intensity, non-motorized human use and were a minimum of 500 m from any open road or motorized trail.

If road densities become too great, secure habitat for bears could become isolated islands surrounded by roads and travel among secure areas can become hazardous for a bear (Schwartz et al. 2010b). Schwartz et al. (2010b) suggested, therefore, that as the amount of secure habitat declined, road density should also decline to reduce hazards to grizzly bears. They felt that management required balancing road density standards with the amount of secure habitat available.

Because of the increasing presence of roads and humans on roads within grizzly bear range, there are some areas where grizzly bears may not be able to avoid humans and still find required food resources (Gibeau et al. 2001, 2002; Proctor et al. 2008; Roever et al. 2008a,b). In these environments, if the best feeding habitat within a bear's home range is interspersed with roads, then a bear will often have to use it despite being more likely to be killed by humans (Graham et al. 2010, Schwartz et al. 2010b, Boulanger et al. 2013). Food-rich habitats that attract bears to high-risk areas can serve as local population sinks (Delibes et al. 2001, Naves et al. 2003, Nielsen et al. 2006, Schwartz et al. 2010b, Nielsen et al. 2010). Identifying higher quality grizzly bear habitats based on food availability or other metrics of bear use, such as radio-telemetry occupancy, can be misleading for management and conservation action if those same sites had a higher risk of human-caused mortality. Consequently, research in Alberta and British Columbia has incorporated mortality risk models (Nielsen et al. 2004b, 2010) with grizzly bear habitat use models as surrogates of population fitness to identify attractive mortality sinks (sink-like habitats) and secure, high-quality habitats (Nielsen et al. 2006, 2010; Nielsen 2011).

Boulanger and Stenhouse (2014) suggested that road densities >0.75 $km/km^2$ in Alberta were associated with grizzly bear population decline when female reproductive-state specific survival was considered and >1.25 $km/km^2$ when all females were considered regardless of reproductive state. They found that higher road densities were strongly associated with lower female survival and this became a limiting factor in population growth when road densities passed these identified thresholds. This work is being used to establish road densities targets of 0.60 $km/km^2$ for "Core conservation areas" in Alberta where grizzly bears are managed for population growth. In other occupied areas with long term stability as a goal, the maximum road density target will be 0.75 $km/km^2$.

MacHutchon and Proctor (2015) found that the average open road density (restricted roads were considered closed and trails were not considered) in the trans-border Canada-U.S. South Selkirk and Yahk subpopulations together was 1.0 $km/km^2$. However, 23 adult female grizzly bears had 95% kernel home ranges with an average open road density of 0.60 $km/km^2$. The trans-border South Selkirk subpopulation, which had an estimated annual growth rate of ~2%, had an average open road density of 0.92 $km/km^2$ whereas adult females averaged 0.39 $km/km^2$. In contrast, the trans-border Yahk subpopulation, which had experienced population decline over much of the past 25 years, had an average road density of 1.2 $km/km^2$ and adult female home ranges averaged 0.90 $km/km^2$. Much of the U.S. portion of the Yahk subpopulation is managed for a road density of 0.60 $km/km^2$ while the B.C. side has an average road density of 1.60 $km/km^2$.

Within B.C., the South Selkirk subpopulation had an average open road density of 1.20 $km/km^2$ whereas adult female grizzly bears had 95% kernel home ranges with an average open road density of 0.43 $km/km^2$. The B.C. Yahk had an average open road density of 1.60 $km/km^2$ whereas adult female home ranges averaged 1.40 $km/km^2$. The old South Purcell GBPU (now within the Central Purcell GBPU) had an average open road density of 0.62 $km/km^2$ whereas adult female home ranges averaged 0.55 $km/km^2$.

Another metric MacHutchon and Proctor (2015) used for the effect of human access on grizzly bear habitat was the proportion of an area that was >500m from an open road in polygons >10 $km^2$ (as above, restricted roads were considered closed and trails were not considered), which they referred to as "secure habitat". Secure habitat compliments the road density metric by reflecting the distribution of open roads across an area. For example, a road density of 1.0 $km/km^2$ that is distributed evenly could have a secure habitat proportion of 0 after all roads were buffered by 500m. However, in practice roads are not distributed evenly. The B.C. Yahk has a relatively high open road density of 1.60 $km/km^2$ and its proportion of secure habitat was 24%. In this context of high open road density and low available secure habitat, adult female bears in the B.C. Yahk had home ranges averaging 31% secure habitat. In contrast, the B.C. South Selkirk had an average open road density of 0.92 $km/km^2$ and 50% secure habitat and in this context adult female bears had home ranges averaging 75% secure habitat. Across both the B.C. Yahk and South Selkirk subpopulations adult females had home ranges averaging 60% secure habitat.

All 23 adult female grizzly bears measured in the trans-border South Selkirk and Yahk subpopulations had 95% kernel home ranges with open road density less than what was available in their ecosystem and secure habitat more than what was available. These consistent results suggested adult female grizzly bears were selecting home ranges to minimize the amount of open road to the extent possible, which may have represented the best available habitat where adult females could survive.

Lower road density and higher proportion of secure habitat in the trans-border South Selkirk was associated with a population increase. In contrast, higher road density and lower proportion of secure habitat in the trans-border Yahk was associated with population decrease. These patterns are consistent with the hypothesis that excessive road density contributes to female mortality and thus influences population trend. This does not necessarily prove that managing human access is necessary to recovery grizzly bears. However, these patterns are consistent with results found in other jurisdictions (Mace et al. 1996, Wakkinen and Kasworm 1997, Schwartz et al. 2010, Boulanger et al. 2013, Boulanger and Stenhouse 2014) some of which have found a negative association of road density with female survival, an important population characteristic often responsible for population trend.

In contrast to the above, although most bears killed by people were near roads, McLellan (In review) did not feel that increasing road density necessarily resulted in higher grizzly bear mortality in the Flathead River valley unless the overall number of grizzly bear or ungulate hunters had increased. However, the number of hunters actually declined over his 33 year study period. McLellan (In review) suggested the abundance of huckleberries growing in the mountains above most human activity in largely road-less areas permitted the Flathead valley population to expand in spite of significant industrial development and human activity associated with a road network at lower elevations. In this way, the grizzly bear population was not negatively affected by the road network or road density per se, however they did benefit greatly by having high quality habitat in road-less (secure) areas where they were largely undisturbed by people.

Population fragmentation results when transportation or service corridors become a significant barrier to movement with resultant demographic and possibly genetic consequences (Mace et al. 1996, Gibeau 2000, Proctor et al. 2005, 2012). Transportation corridors alone (e.g., major highways), but most often, transportation corridors acting cumulatively with human settlement and activity can create areas that bears will rarely occupy or cross (Gibeau 2000, Proctor et al. 2012). Proctor et al. (2012) detailed the human-induced fragmentation status of grizzly bears in southeast B.C., southwest Alberta, and the northern USA. Subpopulation boundaries were derived from genetic discontinuities and evidence of reduced inter-area movements of female bears and to a lesser degree male bears due to fragmentation by settled valleys and major highways. The resulting subpopulations were characterized by the varying numbers of bears they contained and the amount of reduced inter-change with their neighbours, particularly of female bears.

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