Wildlife-related Road Impacts in the Yellowstone to Yukon Region
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an·i·mal (ănˈe-mel) *noun* [Lat.< *animalis*, living < *anima*, soul.]
1. A multicellular organism of the kingdom Animalia, characterized by the capacity for locomotion, fixed bodily structure, restricted growth, nonphotosynthetic metabolism, and an ability to recognize and respond to stimuli.
(Webster's II. New College Dictionary)

Introduction

The very definition of an animal implies movement. Animals move across landscapes to meet daily, seasonal, and lifetime needs. Such movements are necessary for survival of individuals and the persistence of the population and species. Movements occur across a wide range of scales from daily movements (meters to kilometers) to seasonal migrations (tens to hundreds of kilometers) to lifetime movements (thousands of kilometers in sum). A male grizzly bear in Yellowstone, for example, requires about 900 km^2 of habitat during his lifetime and will disperse, on average, about 200 km when he is weaned and leaves his natal area. The longest recorded dispersal is 800 km. Grizzlies are found today primarily in mountainous areas and they have come to symbolize wilderness and intact ecosystems; they serve as an index to the health of the environment all the way from Yellowstone Park to the Yukon and beyond. Throughout this region also, grizzlies have come to symbolize how human activities and developments create barriers to animal movements, fragment the natural landscape, and impact the functions of ecosystems.

The Yellowstone to Yukon region is an area of wide conservation concern. This region, which follows the spine of the Rocky Mountains north to south, has been used as a movement corridor by plant and animal species since time immemorial. During the Pleistocene Epoch of the Quartenary Period a series of ice ages resulted in two large ice caps being formed across what is now Canada and parts of Alaska: the Laurentian ice sheet over most of Canada, and the Cordilleran ice sheet along the Pacific coast of Canada. As the climate warmed at the end of each ice age, these ice sheets receded and opened a corridor between them; the Mackenzie Corridor. As the ice sheets continued to melt and this corridor widened, it became vegetated and animals and plants occupied the land. Over time their distributions, or ranges, expanded moved northwards or southwards. Cold-tolerant plants of the tundra adjacent to the ice sheets were the first to invade. Later shrubs and eventually trees moved in from the south and expanded their range northward as the warming climate permitted. Animals which were adapted to the changing habitats followed the plants. After the Wisconsinan ice age, the ancestors of modern plants and animals used this corridor initially to reach their current distributions. As the ice disappeared and forests expanded, forest-dwelling animals used the slopes and valleys of the Rocky Mountains to expand their ranges. Animals still use these ancient pathways for movement and dispersal.

The Mackenzie Corridor lies along the Eastern Front of the Rocky Mountains; along the eastern boundary of what we call the Yellowstone to Yukon region. As the climate changes in the future, plants and animals will attempt to shift in distribution from north to south in response to optimal conditions for survival and reproduction. This time however, they will encounter barriers that have never before existed; these are the barriers caused by human developments. The nature of those barriers may change somewhat in response to the changing climate, but they will remain in place. Roads, cities, agriculture, and other habitat alterations will not move south to north, and it is certain that they will prevent many plants and animals from doing so as the climate changes.

In a more immediate context however, animals currently move throughout the Yukon to Yellowstone region to meet daily, seasonal, and lifetime needs. Despite extensive development and habitat alteration by humans, most of the region still contains the full complement of large native predators present at the time that humans arrived on this continent, as well as their requisite prey species, and other animals. These native animals and the plants that provide them with habitat (shelter, food, water) form the basis of ecosystems. Ecosystems are dynamic systems composed of biological elements (species) in a physical environment. The interactions between species act to regulate the flow of energy that originates from the sun, is captured by plants, and is passed on through the web of species. When ecosystems operate optimally, as their species have co-evolved to function, energy is efficiently utilized and the physical environment is maintained in a condition that facilitates natural processes. Resources such as air, water, and soil are purified and enriched so that they can also be efficiently utilized by living species; including man.

Human developments and other alterations of natural habitat act to fragment animal populations and habitat, and to restrict movements. In the short term, restricted movements can have negative impacts on populations and ecosystem functions. In the long term, restricted movements can reduce gene flow and have negative impacts on metapopulations and species. To maintain biodiversity and ecosystem functions in both the short and long term it is necessary to maintain habitat connectivity so that individual animals can move across the landscape. Roads, railroads, trails, and other linear developments often reduce or eliminate animal movements and habitat connectivity as discussed below.

The Effects of Roads

Roads have a profound impact upon the distribution and behavior of wildlife populations. The greatest impacts can be viewed as either; those which increase human access, or those which act as barriers to wildlife movement. The building of roads and providing of increased human access to wildlife habitats has been identified as having negative effects on many species (Mattson and Knight, 1991; McLellan and Shackleton, 1988; Mace and Manley, 1987). Road construction is an integral part of most of the current or planned projects in the Y2Y area, many of which are timber sales or oil and gas development. Most of the wildlife species that are listed or considered as threatened or endangered have become so as a result of habitat loss. Most of the loss of habitat is due to direct removal of important habitat; primarily old growth and other late seral stages of vegetation; and to increased human disturbance resulting in the effective loss of otherwise adequate habitat to species that are sensitive to human activities.

The Y2Y is facing impacts that much of the world has already experienced: habitat reduction and fragmentation at a variety of spatial scales has been widely acknowledged as a primary cause of the decline of many species worldwide (Ehrlich 1986, Lovejoy et al. 1986, Harris 1984). Habitat fragmentation generally leads to smaller and more isolated animal populations. Smaller populations are then more vulnerable to local extinction due to periodic extreme events (e.g. fires, disease, etc.) (Shaffer 1978, 1981; Gilpin and Soule 1986), and they are more susceptible to the negative effects of inbreeding depression. With increasing human development, however, wildlife habitat in the region is becoming ever more fragmented. New roads, housing developments, and natural resource extraction activities have caused major changes in the natural landscapes over the past few decades, and in the process have removed or isolated areas of habitat formerly available to wildlife. Projections are for this trend of habitat fragmentation to continue and accelerate, as the U.S. northern Rockies is one of the fastest growing regions in the country in terms of human population (USDA Forest Service 1996). Similar trends are occurring in Canada, particularly in the southernmost parts of Alberta and British Columbia near the U.S. border.

Roads provide access to areas, which result in housing and other developments, which result in more roads. To reduce the isolation of habitat fragments, many conservation biologists (e.g. Noss 1983, 1987; Noss and Harris 1986; Craighead et al. 1998; Craighead and Vyse 1995; Paetkau et al. 1998) have recommended maintaining landscape "connectivity"--preserving habitat for movement of species between remaining fragments. To maintain biodiversity and ecosystem functions throughout Y2Y it may be necessary to preclude the construction of roads in the few areas which are still undisturbed, to remove some roads in areas of critical wildlife habitat, and to make existing roads and other barriers more permeable or “friendly” to wildlife. The effects of roads on wildlife have been summarized in several bibliographies (Joslin andYoumans 1999, Jalkotzy et. al. 1997). Effects of roads on several species of concern in the Y2Y region are discussed in the following sections.

Considering the high degree of disturbance caused by the current level of human activities to wildlife species and habitat near existing transportation routes, any incremental increase in negative impacts, short-term or long term, such as additional roads, developments, or resource extraction, will have the cumulative effect of reducing wildlife habitat. As habitat is reduced, either directly or indirectly, populations of wildlife species become smaller in size and more isolated. This increases the risk of local extinction, and for threatened or endangered species it increases the risk of global extinction. For rare species in the Y2Y the cumulative impacts of human activities are significantly increasing the risk of extinction.

Grizzly bears and roads

Effects of human activities on grizzly bears are complicated by the relationship between the habitat type, the spatial distribution of habitat and disturbance, and the type of disturbance or mortality. Despite the variation in habitat and disturbance factors, there are consistent effects of human activities on bears at the local level. Although bears in Yellowstone and Montana are fully protected, human caused mortality comprises 86-91% of adult bear mortality (Weaver et al., 1996). Female mortality is particularly critical to population viability so that even incremental increases in mortality risk or disturbance are a threat within occupied habitat (Mattson and Reid, 1991; Mattson and Craighead, 1994).

Roads have been shown to be the most important variable correlating human influence on grizzly habitat. Illegal killing and management control (removal of habituated bears) are the two main sources of adult bear mortality in the Greater Yellowstone Ecosystem or GYE (Mattson et al. 1987, Weaver et al. 1996), and both are associated with roads. Road use by humans may also disrupt bear behavior and social structure, reduce the availability of adjacent foraging habitats, and create barriers to movement (Archibald et al. 1987, McLellan and Shackleton 1988, McLellan 1990). These effects may extend up to three kilometers from primary roads and one to 1.5 km from secondary roads (Kasworm and Manley, 1990; Mattson and Knight, 1991b). In the GYE these buffer areas represent 32.9% of, but account for 70.3% of bear mortalities (Mattson and Knight 1991b), therefore the mortality risk is almost five times higher near roads (Doak 1995). Craighead et al. (1995) concluded that road densities higher than 1km/6.4 km2 (one third the threshold set by agencies) are suboptimal for bears.

Recreational development increases bear mortality risk and alienates bears from preferred habitats such as riparian areas. The effect of developments on mortality extends up to 6 km from the site (Mattson and Knight 1991b). Even non-motorized trails may be avoided to a distance of 300 m (Kasworm and Manley 1990, Mace et al. 1996). The impact of recreational development and associated roads reduces the ability of national parks to function as core areas (Gibeau et al. 1996). For example, Yellowstone National Park contains 867 km of roads and sees more than three million visitors a year (Craighead et al. 1995). Bears inhabiting the "multiple-use" lands surrounding the parks face additional threats. The historical decline of the grizzly was associated with the expansion of livestock grazing, especially of sheep, and associated predator control (Peek et al. 1987, Mattson 1990). Livestock depredation-associated killing remains the second most important mortality source for bears in Canada (McLellan 1990). Recent movement of bears into the national forests northwest of Yellowstone may reflect a decline of sheep grazing on public land (Peek et al. 1987). Mineral and gas exploration forms another important disturbance source, primarily through associated road development (McLellan and Shackleton 1989, McLellan 1990).

Grizzly bears have been extirpated from the lowlands that once supported much of their population and they are now generally confined to higher-elevation regions in the Rocky Mountains. Within these regions, human development often converges with the critical lower elevations in spring habitat (Mattson et al. 1987, Mace et al. 1996, Gibeau et al.

1996). Grizzly bear dispersal across human dominated landscapes is often associated with an elevated mortality risk because they are attracted to human associated food sources (Mace and Waller 1998, McLellan et al. 1999). Subadult females establish home ranges near their natal home ranges; either overlapping with, or adjacent to, their mother's home range (Craighead et. al. 1998). Thus, range expansion or re-colonization of empty habitat requires contiguous habitat within which females can establish home ranges, breed, and their female offspring can do likewise. Population expansion occurs incrementally; one female home range at a time.

Grizzly bears are distributed near the southern edge of their North American range in a series of occupied peninsulas of habitat along mountain ranges (McLellan 1998). "Offshore" from the tips of peninsulas there are elict island populations in the North Cascades of southern British Columbia (McLellan 1998) and the Cabinet Mountains of Idaho and Montana (Kasworm et al. 2000). Iin the southern Selkirk Mountains there is a fragmented island population straddling the U.S. - Canada border (M. Proctor, unpublished data). As the human population expands in southern Canada, vehicle traffic along transportation corridors is increasing and adjacent land is being developed and settled (Apps 1997). Proctor et. al. (2002) believe that population fragmentation coupled with excessive human related mortality and habitat degradation is a threat to grizzly bear populations at the southern edge of their North American distribution. Population isolation is a result of the peninsular shape of their distribution. Areas such as the Selkirk Mountains of southern Canada have an isolated a population of approximately 100 bears (M. Proctor unpublished data). Male bear movement has been reduced some fraction of historic levels and there is very little if any female movement across the Highway 3 corridor in the Rocky Mountains. Prevention of female dispersal effectively prevents range expansion or the recolonization of unoccupied habitat. Continued development may further decrease bear movements, and gene flow, across this highway-based barrier.

Proctor and others (Proctor et. al. 2002) recommend the establishment of linkage zones that connect the best available grizzly bear habitat at several locations across this corridor as suggested by Apps (1997). These zones would offer potential benefit to other species as well.

High-volume roads like the Trans-Canada Highway near Banff are more of a barrier to grizzly bears than to black bears. Grizzlies avoid underpasses, but black bears use them (Woods and Munro 1996). The only effective barriers to grizzly dispersal (other than very large bodies of water) are caused by human activities (Craighead and Vyse 1996). Although grizzlies are capable of long distance dispersal, none of 460 radio-tagged grizzlies have traveled between the large core reserves in the Northern Rockies within the past twenty-five years (Servheen, personal communication reported in Weaver et al. 1996). It is likely that barriers caused by human activities have impeded these longer movements since grizzlies in contiguous habitat unaltered by humans often travel this far.

Wolves and roads

Human activities have been shown to influence the distribution and survival of wolves (Thiel 1985, Fuller et al. 1992, Paquet 1993, Mladenoff et al. 1995 Mech et al. 1995, Paquet et al. 1996). Human-caused mortality is a major cause of displacement (Fuller et al. 1992, Mech and Goyal 1993) but little data exist on wolf tolerance of indirect human disturbance. Several studies have systematically examined human population density and wolf distribution. Wolf pack territory size ranges from 210 km^2 in Minnesota to over 1700 km^2 in Alaska. In Northwestern Montana they range from 780 to 1040 km^2. Lone wolves may range over 2600 km^2 (USFWS 1994). Overall, wolves selected those areas that were most remote from human influence and most wolves were in areas with less than 1.54 humans/km2 in Minnesota (Mladenoff et al 1995). In Italy, wolf absence was related to human density, road density, and urbanized areas but the specific effects of each factor could not be distinguished (Dupre et al in press).

In the Bow River Valley of Alberta (Banff) wolves used disturbed habitats less than expected which suggests that the presence of humans alters wolf behavior (Paquet et al 1996). However, very low intensity disturbance (<100 people/month) did not have a significant influence on wolves, and no effect could be documented on the ecological relationships between wolves and their prey. At low to intermediate levels of human activity (100-1,000 people/month) wolves were dislocated from suboptimal habitats. Higher levels of human activity partially displaced wolves but did not cause complete abandonment of preferred habitats. In portions of the Bow River Valley where high elk abundance was associated with high road and or human population density, wolves were completely absent. Overall, habitat alienation resulted in altered predator/prey relationships (Paquet et al. 1996).

Key components of wolf habitat are a year-round prey base (ungulates and small mammals), suitable denning and rendezvous sites, and protection from human-caused mortality (USFWS 1987: Northern Rocky Mountain Wolf Recovery Plan). Because gray wolves are extremely adaptable and can utilize a wide variety of habitat types and prey animals, responses of wolves to human densities, including roads and other emplacements, may not be comparable among ranges. One study found that human activity within 0.6-mile of a den site caused the wolves to abandon the site and move the pups (Chapman 1979a, 1979b).

Roads, by increasing human access, have been shown to negatively affect wolf populations at local, landscape, and regional scales. At local scales this disturbance can be measured as the distance from roads: an aviodance zone of 500m was documented in Banff (Paquet et al 1997), and wolves in Alaska showed a negative response up to 5 km from roads. However, in winter wolves in Alberta were attracted to roads for ease of travel (Paquet, unpublished data).

Road density is a relevant index to human disturbance at regional and landscape levels (Mladenoff et al. 1995, Boitani et al 1997). Studies in Wisconsin, Michigan, Ontario, and Minnesota have shown a strong relationshipo between road density and the absence of wolves. Wolves were generally not present where the density of roads exceeded 0.58 km/km2 (Thiel 1985, Jensen et al. 1986, Mech et al. 1988, Fuller 1989). Road density was much lower in pack territories (0.23 km/km2 in 80% use area) than in random nonpack areas (0.74) or in the region overall (0.71) in Wisconsin, Minnesota, and Michigan, where road density was the strongest predictor of wolf habitat favorability out of five habitat characteristics and six indices of landscape complexity (Mladenoff et al. 1995). Few areas of use exceeded a road density of >0.45 km/km2 , in Minnesota road densities of the primary range, peripheral range, and disjunct range of wolves were all below 0.58 km/km2 (Mladenoff et al. 1995). High road densities may constitute a barrier to wolf dispersal (Jensen et al. 1986). Research in Wisconsin and Minnesota has demonstrated a negative relationship between high road densities and wolf populations (Thiel 1985; Mech et al. 1988). However, wolves may demonstrate less road avoidance during dispersal, where the natural prey base has been depleted, or where human densities are low (Frederick 1991).

Carroll et al (draft manuscript) report that road density effects may not apply to areas on which public access is restricted. For example, Mech (1989) found that wolves used an area with a road density of 0.76 km/km2 but it was adjacent to a large, roadless area. He speculated however that excessive mortality experienced by wolves in the roaded area was compensated for by individuals that dispersed from the adjacent roadless area. Also wolves on Prince of Wales Island Alaska use areas with road densities greater than 0.58 km/km2 . This may be due to the limited options wolves have for relocation when they live on islands or insularized landscapes (Carroll et al draft). Road density effects thus appear to be influenced by the landscape context in which wolf territories occur. Road density thresholds in the Rocky Mountains may differ from those reported in the above studies (Weaver et al. 1996).

Wolves may avoid areas depending upon the type of use the road receives (Thurber et al. 1994). In some cases wolf absence may be a direct result of mortality associated with roads (Van Ballenberge et al. 1975, Mech 1977b, Berg and Kuehn 1982). This relationship appears to result primarily from increasing vulnerability of wolves to human-caused mortality at higher road densities (Frederick 1991; Mech 1970). Wolf packs in hunted areas in Canada often use adjacent areas where access is limited (Paquet et al. 1996) so the effects of road density may be less in the U.S. due to hunting restrictions on wolves.

However, even in areas where protection of wolves is high, 90% of mortality is human caused (Pletshcher et al. 1997). Despite full legal protection, 80% of known wolf mortality in a Minnesota study was human-caused (Fuller 1989) and Mech (1989) reported 60% mortality due to human causes in a roaded area while only 36% of mortality was human caused in an adjoining region without roads. On the east side of the central Rockies in Canada human caused mortality was 95% of known wolf death and 36% of that was related to roads (Paquet 1993). Wolves in Minnesota continue to avoid populated areas and occur most often where road density and human population are low (Fuller et al. 1992).

Mountain lions and roads

Mountain lions are generalists in habitat use and are behaviorally adaptable to a wide variety of ecological conditions, (Weaver et al 1996). Optimal cougar habitat contains 3 things: (1) prey species, (2) vegetative cover, and (3) steep, rugged terrain. The primary prey species in the Rocky mountains are mule deer, elk, and mountain sheep (Hornocker 1970, Seidensticker et al. 1973, Koehler and Hornocker 1991, Ross and Jolkotzky 1992, Williams 1992). Preferred cover types are coniferous or deciduous trees, and large shrubs. Sufficient plant cover, plus steep terrain, enables cougars to successfully stalk prey animals (Hornocker 1970a 1970b, Spalding and Lesowske 1971,Seidensticker et. al.1973, Logan and Irwin 1985, Lindzey 1987, Laing and Lindsey 1991, Murphy et. al.1991, Williams 1992, Ross and Jalkotzy 1992, MDFWP 1995). Mixed conifer types in steep areas are ideal in that they provide both forage for prey and vegetative or topographic stalking cover (Hornocker 1970, Logan and Irwin 1985). A strong seasonal component to habitat selection is evident in the Rocky Mountain region. In Idaho, mountain lions preferred rocky, open, southwest aspects and drier Douglas-fir (Pseudotsuga menziesii) forest types in winter, while selecting for mesic Engelmann spruce (Picea engelmannii)/subalpine fir (Abies lasiocarpa) forest without rocky areas in summer (Dixon 1982, Koehler and Hornocker 1991). Mountain lions can occur at all elevations but prefer mixed wood and coniferous vegetation and so tend to avoid alpine areas. Prey habitat is primarily open woodland and forest, so interspersion and forest edge may be positively correlated with mountain lion abundance (Dixon 1982). Terrain ruggedness, a function of aspect variability and slope, was found to be a more significant predictor of cougar habitat than were vegetation variables (I. Ross, pers. comm.).

Mountain lion distribution is probably restricted by the availability of winter prey. Cougars can easily disperse to distant areas within the northern Rockies provided that human activities are not significant barriers to dispersal. Telemetry studies in Arizona and Utah demonstrated that mountain lions consistently concentrated their activities in areas where road densities were lower than average for the region. They crossed improved dirt roads and hard-surfaced roads less frequently than unimproved roads, and male home ranges were selected with road densities lower than the study area average, no recent timber sales, and few or no sites of human residence (Van Dyke et al. 1986). Logging my lower habitat value by decreasing stalking cover and increasing human access. Although resident animals avoid semi-developed areas, transient lions may use them, especially nocturnally (Van Dyke et al. 1986, Beier 1993, 1995). Mortality rates from roadkill and other sources may be high in some areas (Beier 1993,1995). The most serious threat to western mountain lion populations is degradation of habitat resulting from residential developments, recreational developments, and road building for access to residential, recreational and industrial activities (M. Jalosky pers. comm. cited in Carroll et. al. 1998). In Montana in 1996-97, 7 of 8 radio-collared mountain lions were shot by hunters or ranchers when they left protected habitat (T. Enk pers. comm.).

The mountain lion has relatively high ecological resilience due to its behavioral plasticity and generalist habitat associations (Weaver et al. 1996). Although still widely distributed throughout the Rocky Mountain region, itheir status is not secure in all areas. Unlike other large carnivores, they still inhabit most, if not all, of their former range in the Rocky Mountains. This is largely due to the conservation of their prey habitat and populations (Quigley et al. 1990). Overall, the protection, management, and enhancement of prey habitat and populations are a major sustaining factors for mountain lion populations. Southern Alberta is near the northern limit of the species' range (Dixon 1982). Mountain lions can occur at all elevations but prefer mixed wood and coniferous vegetation. Mountain lions are closely tied to elk and deer as their main prey so that conserving mountain lions often amounts to conserving elk and deer (or in come cases bighorn sheep) populations and habitats.

Lynx and roads

The periodic irruptions associated with the high points of cycles in the boreal forest may be important as a source of dispersers for augmenting southern populations (Mech 1980, Koehler and Aubry 1994). This would make maintenance of regional connectivity important. During these irruptions, long-distance dispersal of 300-500 km has been recorded (Mech 1977a, Brainerd 1985). In moving between denning and foraging habitats, lynx select areas of high canopy closure and avoid open areas (Koehler 1990). Openings greater than 100 m in width may disrupt movement patterns (Koehler and Britell 1990). Coarse-scale connectivity may be especially important for southern populations that inhabit fragmented patches of boreal habitat. At the landscape level, we might expect lynx habitat requirements to include optimal interspersion of foraging and denning habitat. This could be created by an uneven-aged mosaic of early-seral and mature forest (Koehler and Britell 1990). The patchy fire regimes of certain high-elevation forest types creates such a mosaic, while retaining high levels of coarse woody debris (Agee 1993).

Timber harvest techniques have been proposed as an alternate method of creating such a mosaic (Koehler and Britell 1990). However, the effects of logging on lynx habitat remains a subject of debate. The recommended methods, such as dispersed cutblocks, contradict recommendations for maintaining area-sensitive interior-habitat specialists such as the marten (Hargis and Bissonette 1997). In addition, mature forest denning habitat may already be limiting in western forests subject to timber harvest. Further harvest of older stands, even if it led to increasing prey densities, might have negative effects on lynx populations. The continuing decline in lynx distribution in the western U.S. and southern Canada, despite the presence of early-seral prey habitat, much of it due to timber harvest, suggests that higher-level constraints may be limiting population viability.

Conservation organizations cite the increase in road access into high-elevation areas due to logging and other development as a problem (National Wildlife Federation 1991). Direct mortality from roadkill was the major cause of low survival for reintroduced lynx in New York state (Brocke et al. 1991). Trapping mortality can be high in Canada, especially for males and during irruptions when much of the population is nomadic (Carbyn and Patriquin 1983, Koehler and Aubry 1994). There is no trapping allowed for lynx in the U.S., where they are listed as Threatened, but there is some degree of incidental trapping in sets that are targeting coyotes, marten, or wolverine. The higher viability of lynx populations in B.C. compared with Alberta may be due to the spatial refugia from trapping provided by mountainous areas (Hatler 1988).

Wolverines and roads

Wolverine distribution and abundance are directly related to food abundance and security. In general they need large undisturbed areas with an abundance of small and large animals. Carrion is an important part of their diet, especially in late winter and spring. Dependence on carrion may link the viability of wolverine to other carnivore populations such as wolves, and wolf poisoning campaigns in some areas have eradicated wolverine (Banci, 1994). Populations probably cannot sustain rates of human caused mortality greater than 7-8% which is lower than in most studies of trapping mortality. Road access thus can increase trapping mortality including incidental trapping.

Wolverine avoid areas of human activity (Copeland 1996; Copeland and Harris, 1994; Krebs, 1998) and habitat requirements may show more parallels with those of the grizzly bear than with those of more closely related carnivores (Carroll et al., draft). They require large areas of habitat with little or no human disturbance (Hash, 1987). Unauthorized access is increasing on public lands on closed and gated roads in conjunction with statewide increase in use of snowmobiles and Off-Road-Vehicles (J. Claar, pers. comm. 1997). Snowmobile traffic in high mountain cirques can disrupt denning and negatively affect reproductive success. In the Lolo Forest along the Idaho-Montana border south of Superior, the only active wolverine den in the entire alpine region was found in a single basin that was inaccessible to snowmobiles (T. O'Connor pers. comm.). Similar areas may be at risk from disturbance by winter recreation such as heli-skiing (Copeland 1996).

The wolverine shows more generalized use of open areas and a wider variety of vegetation types than the marten and fisher (Banci 1994, Copeland 1996). The fossil record shows that pre-settlement distribution included lowland environments (Copeland 1996), and extended as far south as Arizona and New Mexico (Banci 1994). Present distribution of the wolverine, like that of the grizzly bear, may therefore be primarily related to which regions escaped human settlement.

It is possible that U.S. populations are dependent on immigration from Canada, and the low or declining populations in southern B.C. and Alberta are thus of regional importance (V. Banci, pers. comm.). These trends are occurring despite a decline in trapping, and could also be related to logging, oil and gas exploration, and other human development. The southern interior of B.C. is the fastest growing area in the province, with large increases in human settlement, recreational facilities, and backcountry use.
Loss of ungulate winter range to development and reduction in numbers of spawning salmon have affected wolverine food resources in some regions. Landscape level

diversity, such as between dry and wet forest types, allows the wolverine to survive on temporally variable food resources. However, as with the grizzly bear, seasonal movements to use variable resources make wolverine vulnerable to human-caused landscape fragmentation.

Spatial refugia are important for sustaining wolverine populations in southern Alberta , and in Yellowstone National Park (Buskirk in press). Connectivity between the GYE and remnant Colorado wolverine populations, as well as between the Canadian Rockies and U.S. populations in Idaho and the Cascades may be lost if current trends continue. Although male wolverine may successfully cross developed habitat, dispersal requirements for females with young are more habitat-specific. Like grizzly bears, subadult females rarely disperse because, unlike male offspring, they are tolerated near their natal home ranges (Banci 1994). Thus, range expansion or re-colonization of empty habitat requires contiguous habitat within which females can establish home ranges, breed, and their female offspring can do likewise. Population expansion occurs incrementally; one female home range at a time.

Fisher and roads

Fisher are somewhat tolerant of human disturbance, though there is some evidence that females with kits may abandon dens if disturbed (Heinemeyer and Jones, 1994). Powell demonstrated that even low levels of trapping could result in extirpation. Road density was not found to be a significant variable in some fisher studies (Carroll, 1997). However, dispersing fishers in Massachusetts avoided areas of high human population or road density (York, 1996).

Elk and roads

Historically elk were probably the most widespread member of the deer family in North America. They were extirpated from most of their range by 1900 (Boyd and Cooperrider 1986). In Montana they survived in remote, isolated refugia until protection and reintroductions early in this century allowed recovery through much of their former range (Mussehl and Howell 1971).

Declines in elk use of habitat adjacent to forest roads have been documented in most of the North American range (Hershey and Leege 1976, Lyon 1979, Marcum 1976, Perry and Overly 1976, 1977,Rost and Bailey 1974, 1979, Thomas et al. 1979, Ward 1976). Lyon (1983) found that: "evidence was consistent and overwhelming that vehicular traffic on forest roads evokes an avoidance response by elk. Even though habitat near roads is not denied to elk, it is not fully used". As a result of Lyon's analyses U.S. Forest Service guidelines were developed which restrict activities on big game winter range from December 1 through May 15 and elk habitat effectiveness (security areas for elk) requires an open road density standard of 0.75 miles/sq. mile or less. Components of elk security include vegetation density road density, distance from roads, extent of area and size of vegetation blocks, hunter density, timing and length of hunting season and land ownership (MDFWP 1992).

A critical component of habitat, particularly during hunting seasons and winter, is adequate security. Elk security has been defined by Lyon and Christiansen (1990) and others. Further definition and guidelines for retaining elk security west of the Continental Divide in Montana were devised by Hillis et al. (1991). These guidelines were based upon the facts that 1) elk behavior changes in response to the hunting season, 2) elk avoid areas adjacent to roads with vehicular traffic, especially during the hunting season, 3) elk spend more time in dense cover during hunting season than they do before the hunting season, 4) elk movements generally are confined to habitats within a traditionally used home range, and 5) road closures may either increase or decrease elk vulnerability depending upon the influences of cover, topography and hunting pressure, both within and adjacent to a security area (see Hillis et al. 1991 for citations). Security area minimums should be equal to or greater than 250 acres in size, equal to or greater than one half mile from an open road, and should comprise at least 30% of a valid analysis unit (Hillis et al. 1991).

Mountain Sheep and roads

Miller and Smith (1985) examined 1150 behavioral responses of desert bighorns to potential disturbances in Arizona and found that sheep exhibited stronger reactions to 1 or 2 humans on the ground than to parked vehicles or aircraft. Interactions with moving vehicles were not analyzed. In some cases, stress from human disturbances can be serious for individuals and eventually for populations, and was considered to be a factor in the loss of two California populations (DeForge 1981). In general, the closer the disturbance occurs, the farther sheep will move to get away (Hicks and Elder, 1979; MacArthur et. al,. 1979, 1982) but there is a great amount of variability in sheep reactions (Miller and Smith 1985). Also, in addition to overt behavioral responses to human activities, bighorn sheep have been shown to respond at a physiological level, with elevated heart rates and blood cortisol levels, without showing outward signs of stress (Harlow et. al,. 1987; MacArthur et. al., 1982).

Other studies have indicated that in some cases bighorn sheep may not be disturbed by the presence of people (Russo, 1956; Geist, 1971), although these observations were not as quantitative as those of Miller and Smith (1985). In some cases, sheep appear to be able to avoid disturbances caused by most recreational activities (excluding hunting) and such uses were not considered to affect populations (Hicks and Elder, 1979; Purdy and Shaw, 1980, 1981; Hamilton et. al., 1982). Bighorn sheep have become habituated to people and vehicular traffic around gas well sites in Alberta where sheep have abandoned traditional mineral licks in order to lick pipes and equipment containing sodium and other chemicals. Sheep were also found to eat soil containing minerals used in drilling and testing and mitigation measures were proposed to prevent access of sheep to potentially toxic compounds (Morgantini and Bruns, 1988; Morgantini and Worbets, 1988). These studies indicate the possibility (although slight) of impacts from above ground facilities and accidental spills or leaks.

Conclusions

Biodiversity, wildlife, intact functioning ecosystems, and healthy human communities are resources of great value both locally and internationally; the Yellowstone to Yukon region still retains most of the diversity and abundance of native species in healthy ecosystems, and they are shared and enjoyed by many people. The maintenance of this diversity, as development pressures increase, is the challenge of the Y2Y Conservation Initiative. Impacts on wildlife due to disturbance and development are well documented in the scientific literature; to minimize the cumulative impacts continued human population growth requires that new developments be placed in areas which are already disturbed from the point of view of wildlife. Consolidating impacts due to roads, railroads, pipelines, and other linear disturbances is the only practical method of allowing continued development while still retaining sufficient unfragmented habitat necessary for the maintenance of wildlife populations.

To minimize the effects of cumulative impacts on wildlife, road building should be minimized, and no new roads should be constructed in areas that are currently roadless. Completed timber sales, depleted oil and gas fields, and other completed habitat alterations should incorporate road removal or effective closure as a part of the project. Old growth and other late seral stages of vegetation should be left intact wherever possible. Despite its terrain and climate, the Y2Y area has already been heavily impacted by human activities and there are few large areas of undisturbed wildlife habitat left: a management priority on public lands should be to identify and protect those remaining habitats.

The remaining roadless areas are the last pieces of what were once much larger, intact, ecosystems. To maintain these pieces is critical to maintain the health of the ecosystems and to provide clean air, soil, and water for the species that depend upon them. Paradoxically, one of these species is man. To experience a high quality of life, and health; humans, like all other animals, require the optimal functioning of the ecosystems with which they evolved. Social and economic goals however are currently antithetical to ecological needs; humans alter the environment to meet short-term goals at the expense of long-term stability and health. In the Yellowstone to Yukon region there is still enough intact habitat to find a balance; humans can meet their needs realistically while maintaining enough natural habitat to ensure a high quality of life. Native plants and animals can be allowed enough space to coexist with humans. The first step towards finding this balance involves re-thinking our construction and use of roads.

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