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GRIZZLY BEARS AND RESOURCE-EXTRACTION INDUSTRIES: EFFECTS OF ROADS ON BEHAVIOUR, HABITAT USE AND DEMOGRAPHY

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SUMMARY

(1) Roads are an integral part of the development of resource-extraction industries. We wanted to know whether grizzly bears were displaced by these roads from adjacent habitats. Over 7 years, twenty-seven grizzly bears were captured and radio-collared in 264 km^2 of the Rocky Mountains, containing active tree-felling and petrocarbon developments.

(2) Most bears used habitats within 100 m of roads less than expected. This is equivalent to a habitat loss of 8·7%. This is significant because many habitats close to roads contain important bear foods. Avoidance of roads was independent of traffic volume, suggesting that even a few vehicles can displace bears.

(3) Roads and nearby areas were used at night but avoided in the day. Yearlings and females with cubs used habitats near roads more than other bears. These areas may have been relatively secure because they were avoided by potentially aggressive adult males.

(4) Limited data indicated minimal demographic effects during our study, but roads increased access for legal and illegal hunters, the major source of adult grizzly mortality.

(5) When roads are developed for resource industries in grizzly bear habitat, the bear population becomes highly vulnerable unless vehicle access and people with firearms are controlled.

INTRODUCTION

Grizzly bears (*Ursus arctos* Ord) are considered to require wilderness and seclusion from man (Hamer 1974; Craighead 1976), but much of their habitat is being explored and developed by resource-extraction industries (forestry, mining, petrocarbons). Previously ranging throughout western North America, grizzly bears are now classified as a threatened species in the contiguous U.S.A., and there is concern that their requirements are largely incompatible with most resource development. Most published information concerns grizzly bears in areas without resource-extraction industries, such as national parks (see review in LeFranc *et al.* 1987).

There are many levels of bear–industry interaction, but the most immediate concerns the extensive network of roads upon which the industries depend. Roads increase access for hunters and poachers, the probability of vehicle–bear collisions, and the frequency of energy costly flight responses by the bears. Indirect population constraints can result from long-term displacement of bears from areas adjacent to roads. Roads often follow valley bottoms and pass through riparian areas which are frequently used by grizzly bears. If roads do displace bears, it leads either to increased pressure on similar habitats in undisturbed regions, or to the 'loss' of these essential but limited habitats. Some variation in bears' responses to roads has been predicted; adult females with young cubs may avoid areas near roads more than other bears (Zager 1980); darkness acts as cover for bears (Servheen 1981), so they use areas adjacent to roads mostly at night.

Through a long-term investigation of the nature and consequences of their interactions (B. N. McLellan & D. M. Shackleton, unpublished), we hope to determine whether bears and extraction industries can be managed compatibly. This paper presents data on the displacement of grizzly bears from habitats by roads developed for resource-extraction industries (forestry, mining, gas and oil). We tested the basic null hypothesis that grizzly bears use areas adjacent to roads as often as they use areas away from them. We also explored the effects of age–sex class, reproductive status, habitat type, amount of vehicular traffic and time of day on this pattern of use, and the demographic implications.

STUDY AREA

The study was in the North Fork of the Flathead River drainage in south-eastern British Columbia, Canada and adjacent Montana, U.S.A. The river flows at *c*. 1250 m above sea level, through a wide, flat-bottomed valley with rolling hills, and subranges of the Rocky Mountains rising to > 2800 m above sea level on either side. The total study area was a 2820-km^2 composite of the home ranges of all bears trapped and radio-collared in a 264-km^2 core area, centred on the Flathead River (114°85′N; 49°1′W), just north of the International Border.

Wildfires in the late 1800s and early 1900s burned much of the study area (Zager, Jonkel & Habeck 1983). Later, beetle infestations (*Dendroctonus ponderosae* Hopkins and *D. obsesus* Mannerheim) killed many trees, which were then harvested by clearcutting. The valley is a mosaic of young, non-merchantable lodgepole pine (*Pinus contorta* Dougl.), immature larch (*Larix occidentalis* Nutt.) and sub-alpine fir (*Abies lasiocarpa* (Hock) Nutt.), low-gradient riparian areas, several marshes and dry meadows, and numerous clearings and roads. The mountain areas contain mixtures of spruce (*Picea engelmanni* × *glauca*), sub-alpine fir, white bark pine (*Pinus albicualis* Engelm.) and alpine larch (*L. lyalli* Parl.) forests, early succession after burning, snowchutes, alpine meadows, selective cuts and clearcuts, roads, and rock outcrops.

The nearest settlement in Canada is 100 km from the study area, but begins at the border in the U.S.A. Roads were first built from the U.S.A. between 1906 and the 1930s for oil exploration. Since the 1950s, many more roads were developed to fell beetle-killed trees and, in 1980, gas exploration began. Many game species including grizzly bears are hunted in the study area.

METHODS

Using foot snares, twenty-seven grizzly bears (three weaned yearlings, six sub-adult females (2–4 years), four sub-adult males, eight adult females and six adult males) were captured and fitted with radio-collars (Telonics Ltd, Arizona; 164–166 MHz). Between April 1979 and November 1985, bears were relocated from fixed-wing aircraft approximately once each week, and the numerous roads allowed ground tracking more frequently. Locations were made on the ground by taking compass bearings from at least three known map locations.

When a bear was very close, additional bearings were impractical; in steep terrain, although signals bounced or the observer's location could not be established, numerous approximate bearings were taken while walking at least 180° around the animal. Bears were seen frequently under these conditions.

Five distance-from-road categories (DRC) were delineated: (i) 0–100 m; (ii) 101–250 m; (iii) 251–500 m; (iv) 501–1000 m; and (v) >1000 m. Category widths increased with distance from roads because radio-relocations are 'probability areas' not points, so their precision is a function of the bear–observer distance. Most ground locations were made from roads, so narrower distance categories were acceptable for locations near roads.

Roads were separated into three classes: primary roads (main roads leading into the valley); secondary roads (first-order branches off primary roads); tertiary roads (all other roads accessible by two-wheel-drive vehicles). Traffic frequency was sampled opportunistically by counting vehicles (primary roads: $n=241$, 205·4 h; secondary roads: $n=145$, 97·9 h). Vehicles were classed as small or large (>1/2-ton pick-up truck).

Minimum relocation samples sizes for comparisons among individual bears were defined as fifteen relocations per season per bear. The spring season began when bears emerged from dens and lasted until huckleberries (*Vaccinium globulare* Rydb.) ripened. Summer–autumn ran from berry ripening to when bears first moved to denning areas (April–July; August–November).

Home ranges of all bears contained roads. Using the method of Marcum & Loftsgaarden (1980) to estimate resource availability, 1928 random points were located over a map of the study area. For each point, the habitat component (Servheen 1983; Zager 1980), elevation, DRC and class of the nearest road were determined. All points ($\bar{x}=228$ per seasonal range) within the minimum convex polygon of each bear's seasonal range were used to determine the proportion in each DRC.

The observed frequency of radio locations within each DRC was compared with the expected (available) using the *G*-test (Sokal & Rohlf 1981, pp. 704–721); the probability of a type I error was set at 0·05. Confidence intervals were calculated for each DRC using the Bonferroni approach with 90% simultaneous confidence limits (Marcum & Loftsgaarden 1980). Radiolocations separated by at least 10 h were considered independent because a bear could travel between all DRCs in this time; most relocations (96%) were separated by at least 24 h. Frequently, radiolocations for more than one bear were grouped and compared with the sum of random dots from each of these bear's seasonal home ranges. Ranges overlapped, so the same dot could occur within the seasonal range of several bears and be used more than once; therefore, total sample sizes of random dots were reduced to the number of different dots used.

Locating bears during the day often included walking through densely vegetated habitats lacking trails, while night locations could only be made from roads. Consequently, bears located at night were usually individuals that had been located earlier in the day, in parts of the study area with high road densities. It was inappropriate to compare all day and night locations, so samples were paired within 24 h by DRC, and Wilcoxon's matched-pairs signed-ranks test was used. Day–night pairs were also grouped by common DRC to enable comparisons at different distances from roads. If the paired locations fell in different DRCs, the closer category was used for analysis.

Bear locations near dens were omitted because they were affected by factors other than roads. Similarly, locations of bears foraging for huckleberries in high-elevation burnt areas during the summer were not used. Because of a lack of harvestable timber, these burnt areas were 1·5–7 km away from roads, so both their use and availability data were in the >1000 m DRC.

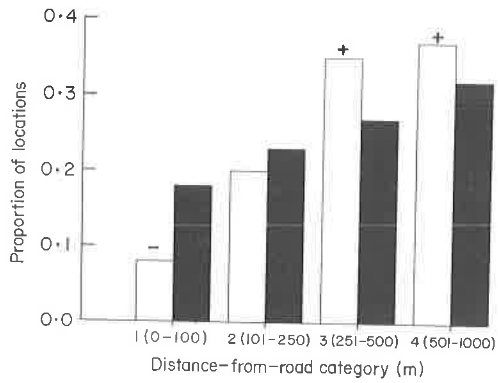

FIG. 1. Observed (□, $n=2279$) vs. expected (■, $n=1380$) use by grizzly bears of the four distance-from-road categories in the Flathead Valley, B.C. Data are combined for all road types, both seasons, ground and aerial radiolocations, and all age–sex classes, between 1979 and 1985. Use differing significantly from expected ($P<0{\cdot}05$) is indicated by + or −. For differences in n values see Methods.

RESULTS

Of the 624 aerial relocations, 32% were > 1 km from roads, compared with 15% of the 2196 made on the ground. This significant difference ($G=86{\cdot}71$, d.f. $=4$) was a result of the radio receiver's limitations rather than a measure of bear use. After omitting data from the most distant DRC, there was no difference between the 422 aerial and 1857 ground relocations of the remaining four DRCs ($G=4{\cdot}71$, d.f. $=3$).

Grizzly bear use of the five DRCs over both seasons combined, using unbiased aerial relocations, differed from that expected ($G=61{\cdot}24$, d.f. $=4$). They used the 0–100 and 101–250 m DRCs significantly less than expected. Ground locations were biased only when > 1 km from a road and, because displacement from roads occurred only in the closest DRCs, aerial and ground relocations were combined for subsequent analyses, omitting data from the most distant DRC.

Use of the four DRCs differed significantly from what was expected in spring ($G=73{\cdot}11$, d.f. $=3$), summer–autumn ($G=78{\cdot}12$, d.f. $=3$), and for both seasons combined ($G=99{\cdot}61$, d.f. $=3$; Fig. 1). In spring, habitats within 100 m of roads were used significantly less than expected but, in summer–autumn, bears used habitats within 250 m of roads less than expected.

Individual variation

Of the twenty-three grizzlies for which we had adequate spring information, fourteen (61%) used the closest DRC significantly less and one used it significantly more than expected. The remaining bears' use of this DRC was not significantly different from expected. No bears used the 101–250 m differently from expected, while six used either the 251–500 or 501–1000 m significantly more and two less, in spring.

The closest DRC was used less than expected in summer–autumn by seven of fourteen bears, while three used the 101–250 m DRC significantly less. Greater use was recorded by seven bears; each in one of the DRCs between 101 and 1000 m.

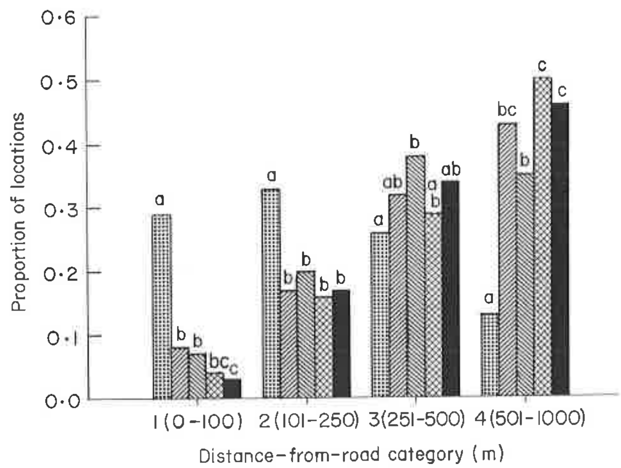

Fig. 2. Relative use (proportion of radio-relocations) by five age–sex classes of grizzly bears of the four distance-from-road categories (DRC) in the Flathead Valley, B.C., between spring and autumn (1979–85). Significant differences ($P<0.05$) among classes in their use of each DRC are indicated by different letters. The number of radiolocations $=n$. ▤ Yearlings ($n=126$); ▨ sub-adult females ($n=605$); ▧ adult females ($n=911$); ▩ sub-adult males ($n=605$); ■ adult males ($n=406$).

Variation among age–sex classes

Weaning yearlings used areas within 250 m of roads significantly more, and those within 500 and 1000 m significantly less than all other classes of bears (Fig. 2). Two of the three yearlings were offspring of radio-collared females and they used the closest DRC significantly more when alone, than when they were cubs with their mothers. Contrary to what was predicted, adult males used the closest DRC significantly less than either adult or sub-adult females (Fig. 2).

Variation within age–sex classes

There was less variation within than among some age–sex classes' use of areas closest to roads. All three weaned yearlings used all areas within 100 m of a road more than expected, the difference being significant for one yearling. Two of these yearlings used the 501–1000 m DRC significantly less. All six adult and three sub-adult males used the closest DRC significantly less, and one individual in each of these age-classes also used the 101–250 m DRC less than expected. Four of five sub-adult and four of six adult females used areas in the closest DRC less than expected.

Female reproductive status and responses

In spring, females with cubs, with yearlings, or alone, used the four DRCs differently ($G=17.59$, d.f.$=6$). When with cubs, they used the closest DRC significantly more than when with older offspring or when alone (Fig. 3). In summer–autumn, the three groups of females used all DRCs similarly ($G=4.31$, d.f.$=6$; Fig. 3).

Influence of traffic

Primary roads were used on average by 1·3 large and 3·5 small vehicles h^{-1}; 0·4 large and 1·5 small vehicles h^{-1} used secondary roads. For most of the year, tertiary roads were

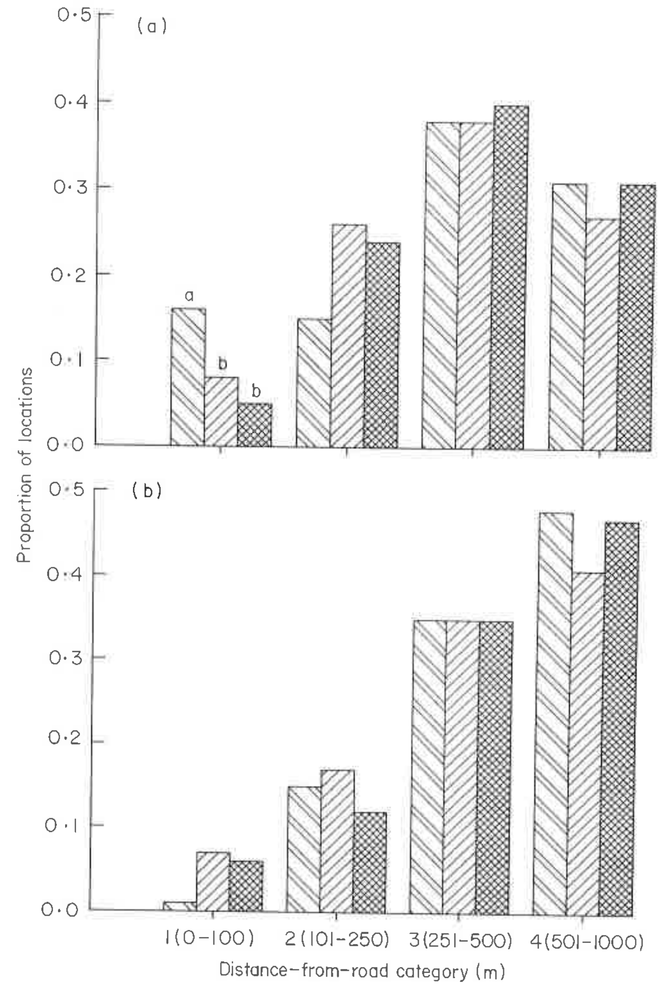

FIG. 3. Relative use of the four distance-from-road categories (DRC) by female grizzly bears of different reproductive status during (a) spring and (b) summer–autumn. Where use of a DRC differed significantly ($P < 0{\cdot}05$) among females of different status, this is indicated by different letters. The number of relocations $= n$. ▧ Females with cubs: (a) $n = 140$, (b) $n = 80$). ▨ Females with yearlings: (a) $n = 182$, (b) $n = 54$. ▩ Females alone: (a) $n = 269$, (b) $n = 55$.

used almost exclusively by ourselves and a group studying wolves. Forestry and gas exploration personnel used them for short periods, and hunters used them frequently in the autumn.

We predicted that bears would use areas adjacent to primary roads less than those adjacent to roads with less traffic, but they did not. For both seasons combined, bears significantly reduced their use only of the 0–100 m DRC in all road classes, and, in general, used the two most distant DRCs more than expected (Fig. 4).

Nocturnal behaviour

Overall, bears used areas near roads significantly more at night than during daylight (Wilcoxon's $Z = 1{\cdot}71$; $n = 121$). When data were subdivided and re-analysed for each

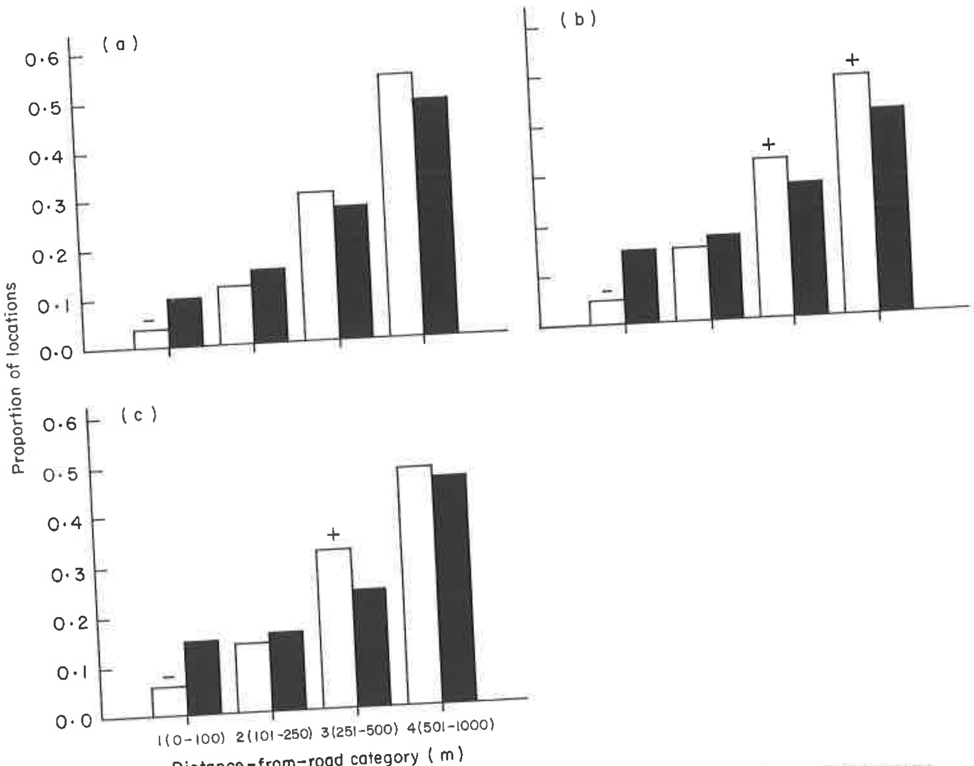

Fig. 4. Observed (□) vs. expected (■) use by all grizzly bears of each distance-from-road category with different amounts of traffic: (a) primary (observed $n=850$, expected $n=568$); (b) primary and secondary: (observed $n=1796$, expected $n=1071$); (c) tertiary roads (observed $n=1582$, expected $n=734$) in the Flathead Valley, B.C. Data represent all spring and summer–autumn seasons in 1979–85. Use differing significantly from expected ($P<0{\cdot}05$) is indicated by + or −. For differences in n values see Methods.

DRC separately, the probabilities of the two distributions being the same were 0·054, 0·066, 0·052, and 0·405 for DRCs 1–4, respectively. With the smaller samples, none of these values was significant, though night use of the three closest DRCs was greatest. For the paired locations, bears were located on roads twelve times, ten during the night. If roads were used equally during day and night, the probability of such an occurrence is only 0·012. We also noted many more fresh bear tracks in mud and snow on roads early in the morning than later in the day.

Influence of habitat

Habitat components were not randomly distributed relative to the DRCs ($G=143{\cdot}61$; d.f. $=18$). For example, most roads were built for removing timber and, not surprisingly, felling units comprised 33% of the habitats within 100 m of roads, but only 4% in the >1000 m DRC. Conversely, riparian areas made up only 5% of habitats in the 0–100 m DRC, and 17% in the 251–500 m DRC. To overcome the lack of independence between habitats and roads, and to allow us to distinguish which the bears were responding to, we compared use of each habitat component with the use expected within each DRC. If roads caused bears to reduce their use of a given habitat component, use of such a habitat should have decreased the closer it was to a road. But, if bears responded primarily to habitats rather than to roads, we should have found no difference in their use of a given habitat among the DRCs.

When the seven habitat components were examined separately, there were adequate data to analyse use of timber and riparian types only, which together comprised 72% of all data used. These provided the densest cover, and we expected grizzlies to be displaced least from these habitats. However, they used timber and riparian within 100 m of roads significantly less than expected in spring, and used timber in this closest DRC significantly less than expected in summer–autumn. These results support the hypothesis that bears were displaced by roads and were not simply avoiding the types of habitat found near roads.

DISCUSSION

Loss of habitats near roads

Most grizzly bears used areas near open roads significantly less than expected. This was equivalent to a habitat loss of 58% in the 0–100 m DRC and 7% in the 101–250 m DRC. For the whole Flathead study area, it represents a loss of 8·7% of the area available to the bears. Further, the types of habitat most often associated with roads are especially valuable to bears, because they contain high-quality foods in spring and autumn.

The bears' reduced use of areas within 100 m of primary, secondary or tertiary roads did not differ, suggesting that even a little traffic is sufficient to displace them. No bear's home range lacked roads or other human activities, so they should have had some opportunity to habituate or adapt to predictable road-related stimuli. Certain aspects of their behaviour may have reduced the degree of habitat loss bears experienced. The first is their use of roads and adjacent areas at night, which supports Servheen's (1981) prediction that darkness offers cover to bears. Obviously, bears cannot use all areas all the time, but by altering their use of areas near roads from daylight to night, they may continue to use a large portion of valuable habitats near roads. Darkness probably provided security cover, but traffic would also be reduced somewhat.

Variation among classes in the use of areas near roads may have had an ameliorating effect. Adult males used habitats near roads less than other classes, while weaned yearlings and some adult females with cubs used these areas more than any other class, contrary to Zager's (1980) prediction. This differential response was also found in black bears (*U. americanus* Pallas; Tietje & Ruff 1983). Adult males sometimes kill cubs and yearlings (Glenn *et al.* 1976; Mundy & Flook 1973; Pearson 1975; Reynolds & Hechtel 1979; Troyer & Hensel 1962), so habitats near roads may have been relatively safe for these vulnerable classes of grizzlies. Females with cubs generally avoid adult grizzly males (Pearson 1975; Russell *et al.* 1979), and an experiment suggested that adult male black bears regulated population density in northern Alberta (Kemp 1972, 1976).

A different response to roads was found only 150 km south of our study area. Here, two female grizzlies used habitats within 199 m of open roads less and two males used such areas more frequently than expected (Zager 1980). The reason for the difference between the two studies could be due to the small sample of four bears, but also to differences in habitat availability. Highly productive, low-elevation habitats in Zager's (1980) study area were eliminated by water impoundment behind the Hungry Horse Dam, restricting bears to steep mountain habitats and narrow side-valleys where there were roads. As in Jasper National Park, Alberta (Russell *et al.* 1979), males frequently used the productive areas at low elevations in the narrow side-valleys, while females used higher sites. In our study area, all age–sex classes used the wide relatively flat valley, and habitat-use patterns were not affected by elevation. Here, as in Tietje & Ruff's (1983) flat study area, human-use areas probably had a more direct effect on age–sex class segregation of grizzlies than did elevation.

Demographic consequences of roads

To be of major concern to wildlife managers, behavioural responses to disturbance must have demonstrable demographic consequences (Shank 1979). Demographic responses do not necessarily follow, even from significant behavioural responses. While unable to demonstrate definitive demographic consequences of the bears' behavioural responses to roads, we can make a preliminary assessment. The population was at a relatively high density during our study (B. N. McLellan & D. M. Shackleton, unpublished), and the survival–fecundity rate of increase, which is a good indicator of how a population is coping with a given condition (Caughley 1977), was positive (B. N. McLellan & D. M. Shackleton, unpublished), indicating that roads were not having a severe effect during our study.

Three characteristics of the study area may have reduced the potential impact of roads on the grizzly bear population. First, bear survival depends greatly on fat reserves obtained primarily in late summer by foraging on huckleberries. In our study area, these grow best in high-elevation, post-fire shrubfields, which do not contain roads and are therefore totally available to the bear population. Second, in the B.C. part of the study area, resource-industries employees make up most of the resident human population. Potential road-related effects on the bears were probably lessened because of some industries' policies (e.g. Shell Canada: no firearms, restricted use of private vehicles, daily garbage incineration). Third, hunting regulations have become more restrictive each year throughout most of the study area, and the annual legal harvest of grizzlies is monitored.

Roads did increase the bears' vulnerability to legal hunters and to poachers by providing ready access. All known and suspected adult and sub-adult grizzly deaths ($n=29$) since 1979 have been due to legal or illegal hunting; most bears were shot from roads (B. N. McLellan & D. M. Shackleton, unpublished). Even though the Flathead grizzly population seems to have absorbed the effects of human access during our short study, the roads' potential as a significant negative, demographic factor remains high. Once roads are developed in any grizzly habitat, the population is placed in a precarious position and management must change accordingly.

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