Grizzly bear use of open, closed, and restricted forestry roads

Robert B. Wielgus, Pierre R. Vernier, and Tina Schivatcheva

Abstract: We investigated grizzly bear (*Ursus arctos*) selection of three road types in the northern United States and southern British Columbia from 1986 to 1991. We hypothesized that grizzly bears select against open (public use allowed), restricted (forestry use only), and closed roads (no public use allowed) in that order. We analyzed use of roads for 11 bears (five females and six males) in an area containing open and closed roads and 11 bears (seven females and four males) in an adjacent area containing restricted roads. We used χ^2 and log–linear models to test for selection of habitat type and distance to road categories. Ten of 12 females and 5 of 10 males (15 of 22 bears) selected against ($P < 0.05$) low-elevation interior cedar–hemlock and for ($P < 0.05$) high-elevation Englemann spruce (*Picea engelmannii* Parry ex Engelm.) – subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). After accounting for habitat, 4 of 5 females and 3 of 6 males (7 of 11 bears) selected against open roads and 3 of 5 females and 0 of 6 males (3 of 11 bears) selected against closed roads. No females ($n = 7$) or males ($n = 4$) (0 of 11 bears) selected against restricted roads. Our results are inconsistent with the hypothesis that bears select against open, restricted, and closed roads in that order. Most females and males selected against open roads, most females selected against closed roads, and no bears selected against restricted roads. The type of human activity along roads plays a role in bear responses to roads, and this aspect should be incorporated into future bear–road studies.

Résumé : Nous avons étudié l'utilisation par l'ours grizzly (*Ursus arctos*) de trois types de chemins dans le Nord des États-Unis et le Sud de la Colombie-Britannique de 1986 à 1991. Notre hypothèse était que les ours grizzly évitent, dans l'ordre, les chemins ouverts (au public), les chemins à accès restreint (limités aux forestiers) et les chemins fermés (au public). Nous avons analysé l'utilisation des chemins par 11 ours (cinq femelles, six mâles) dans un territoire incluant des chemins ouverts et fermés et par 11 ours (sept femelles, quatre mâle) dans un territoire adjacent avec des chemins à accès restreint. Nous avons utilisé le test du χ^2 et des modèles log–linéaires pour les tests de sélection du type d'habitat et de distance par rapport aux routes des différentes catégories. Dix des 12 femelles et 5 des 10 mâles (15 des 22 ours) utilisaient moins les peuplements de pruche et thuya de l'intérieur et à basse élévation ($P < 0,05$) et plus les peuplements d'épinette d'Engelmann (*Picea engelmannii* Parry ex Engelm.) et de sapin subalpin à haute élévation (*Abies lasiocarpa* (Hook.) Nutt.) ($P < 0,05$). En tenant compte de l'habitat, 4 des 5 femelles et 3 des 6 mâles (7 des 11 ours) ont évité les chemins ouverts et 3 des 5 femelles et aucun des 6 mâles (3 des 11 ours) ont évité les chemins fermés. Aucune femelle ($n = 7$) ni aucun mâle ($n = 4$) (0 des 11 ours) a évité les chemins à accès restreint. Nous résultats réfutent l'hypothèse que les ours évitent, dans l'ordre, les chemins ouverts, à accès restreint et fermés. La plupart des femelles et des mâles ont évité les chemins ouverts, la plupart des femelles ont évité les chemins fermés et aucun ours a évité les chemins à accès restreint. Comme le type d'activité humaine le long des chemins influence le comportement des ours, il faudrait en tenir compte lors de nouvelles études sur le comportement des ours en relation avec les chemins.

[Traduit par la Rédaction]

Introduction

The Selkirk Mountains Grizzly Bear Ecosystem (SMGBE) includes parts of southeastern British Columbia, northern Idaho, and northeastern Washington. Grizzly bears within the U.S. SMGBE are classified as threatened by the U.S. Fish and Wildlife Service (Servheen 1990). Bears within the B.C. SMGBE are classified as vulnerable by the Committee on the Status of Endangered Wildlife in Canada (Banci 1991) and threatened by the Grizzly Bear Conservation Strategy of British Columbia (B.C. Ministry of Environment, Lands, and Parks 1995*a*, 1995*b*; Wielgus 2002). Forestry activities are the major anthropogenic activity in the area. Wielgus et al. (1994, 2001) and Wielgus and Bunnell (1995, 2000) studied population dynamics and habitat use of grizzly bears in the SMGBE from 1985 through 1991 and found that population growth rate was marginal because of human caused mortalities near open roads (for a brief review of road – carnivore mortality relationships see Introduction in Gloyne and Clevenger 2001). Forestry roads were also cited as one of the biggest impacts on bear habitat use in the Grizzly Bear Conservation Strategy (B.C. Ministry of Environment, Lands, and Parks 1995*a*, 1995*b*). The

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popular assumption is that bears avoid forestry roads and that this results in habitat loss and reduced fitness attributes such as reproductive success.

Other researchers found that bears appeared to avoid roads (Elgmork 1978; Archibald et al. 1987; Mattson et al. 1987; McLellan and Shackleton 1988; Kasworm and Manley 1990; Mace et al. 1996, 1999). Of those two research programs that studied both female and male bears, Mattson et al. (1987) and McLellan and Shackleton (1988) observed apparent displacement of adult females towards roads because of sexual segregation or avoidance of adult males. McLellan and Shackleton (1988) and Mace et al. (1999) also showed that habitat may influence apparent avoidance of roads. However, only Mace et al. (1996, 1999) examined the relative effects of open roads (all traffic allowed, e.g., forestry and public use) and closed roads (no forestry or public traffic allowed, very limited U.S. Forest Service administrative use only); all others examined the effects of open roads only. No researchers have examined the effects of restricted roads (forestry traffic only, no public use allowed). In this study we use retrospective data (Wielgus and Bunnell 1995) in a mensurative experiment (Eberhardt and Thomas 1991) to test for selection against open, closed, and restricted roads by male and female grizzly bears. The presence of restricted roads in this study area provides a unique opportunity to examine effects of forestry use alone. We hypothesize that use of road corridors will mirror intensity of human use with greatest selection against heavily used open roads, moderate selection against moderately used restricted roads, and no selection against little used closed roads. No sexual segregation or displacement of females by males has been found in this study area (Wielgus and Bunnell 1995), so we expect that the influence of roads on use of space should be unaffected by these intraspecific social factors.

Study area

The SMGBE covers approximately 5700 km^2, with 3000 km^2 in northern Idaho and northeastern Washington and 2700 km^2 in southeastern British Columbia (48–49°N, 116–117°W). We divided the SMGBE into a 1420-km^2 southern study area (south of B.C. highway 3) and a 1994-km^2 northern study area because of different road types and because bears were captured in and tended to restrict their activities to each area (Wielgus et al. 1994; Wielgus and Bunnell 1995; this study). The southern area contained open and closed roads in confounding proximity (Figs. 1*a* and 1*b*). Closed roads were gated or blocked by the USDA Forest Service to prevent vehicle access. The northern study area contained restricted roads (Fig. 1*c*). Restricted roads were gated and (or) posted with warnings of no public access or trespass and stated that traffic was radio controlled and warned against sudden appearance of loaded logging trucks. Vehicle traffic appeared to be relatively heavy on open roads, moderate on restricted roads, and very light on closed roads.

Physiography was mountainous and climate was Pacific maritime/Continental. Vegetation was classified into the Engelmann spruce – subalpine fir (ESSF) (*Picea engelmannii* Parry ex Engelm. – *Abies lasiocarpa* (Hook.) Nutt.), interior cedar – western hemlock (ICH) (*Thuja plicata* Donn. ex D. Don – *Tsuga heterophylla* (Raf.) Sarg.), and alpine terrain (AT) zones (Pojar et al. 1987). The southern study area was composed of 60% ICH, 37% ESSF, and 3% AT. The northern study area was composed of 40% ICH, 45% ESSF, and 15% AT (Fig. 1*d*).

Methods

Trapping and monitoring

We trapped grizzly bears in the southern area 1 May – 30 June from 1985 to 1987 and 8–25 August 1989. Trapping in the northern area occurred from 25 May to 26 July during 1988–1989. We trapped bears using Aldrich leg snares and immobilized them with 4.5 mg ketamine hydrochloride and 2.3 mg xylazine hydrochloride per kilogram body mass. We fitted all bears with mortality sensing “drop-off” radiocollars (Hellgren et al. 1988) and determined sex during capture and estimated age from known birth date or by counting cementum annuli (Stoneburg and Jonkel 1966). We handled bears according to Canadian Council on Animal Care, University of British Columbia Animal Care Certificate No. 890105. For details on trapping, see Wielgus et al. (1994) and Wielgus and Bunnell (1995, 2000).

We conducted aerial radio-telemetry from fixed-wing aircraft (Whitehouse and Steven 1977) at weekly intervals to ensure independence of radiolocation data (White and Garrott 1990). Telemetry flights were conducted from 1 April to 1 November from 1986 to 1991 to monitor grizzly bear habitat use. Flights were conducted from 06:00 to 12:00, so interpretation of habitat use is restricted to daytime only. Locations of bears were plotted on 1 : 24 000 (U.S.) or 1 : 50 000 (Canada) topographic maps and by taking aerial Polaroid photographs of the bear’s location from the aircraft. Locations were later transferred to 1 : 20 000 forest cover maps. Accuracy of locations were determined by placing test collars in known locations, visual confirmations of bears from the air, and by ground searching for fresh bear sign (scats, tracks, digs, hairs) at the estimated location within 1 week of the flight.

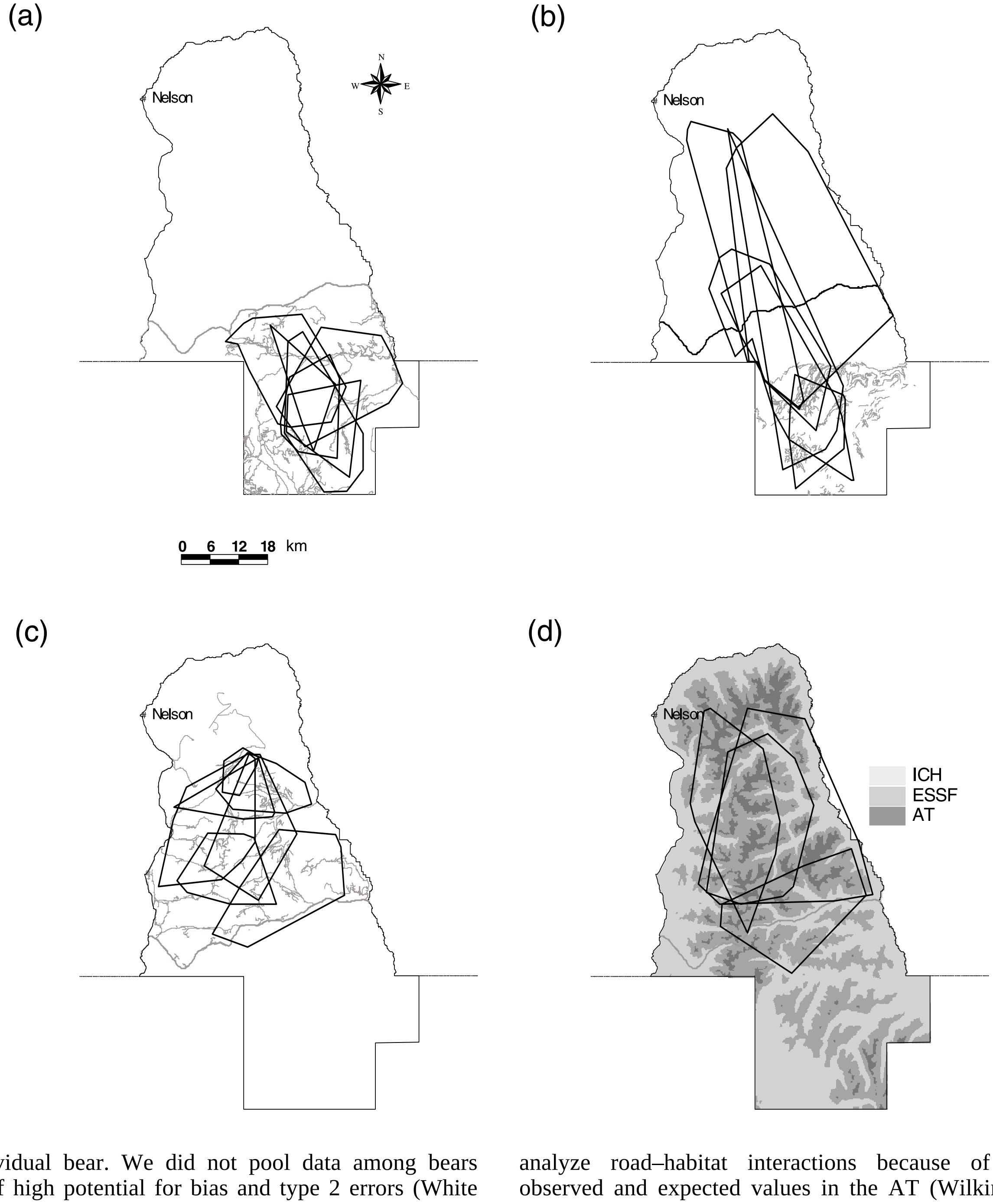
Bear use of habitat and roads

The study area was mapped for forest cover types and roads at 1 : 20 000 scale by forest management agencies. We merged and digitized those maps using ArcInfo/Arcview into a single geographic information system coverage. We classified all highways, roads (navigable by two wheel drive vehicle), and trails (navigable by four wheel drive vehicle) into open, closed, and restricted roads based on existing forest road classifications, interviews with area foresters, and our own site investigations from 1989 to 1991. There were few or no changes in road classification during research from 1986 to 1991.

We partitioned the study area into three habitat types: the low-elevation (<1538 ± 131 m; mean ± SD) ICH zone; the mid-elevation (<1953 ± 95 m) ESSF zone; and the high-elevation (>1953 m) AT zone (Fig. 1*d*). We used these types, because grizzly bear use of road corridors could be confounded with use of them and because they were used by forestry and wildlife management agencies.

We tested for effects of habitat and roads by comparing observed and expected numbers of radiolocations in different habitat types and distance to road categories (DRCs) for

Fig. 1. Home ranges of five southern females (dark lines) and open roads (light lines) in the south (*a*), home ranges of six southern males and closed roads in the south (*b*), home ranges of seven northern females and restricted roads in the north (*c*), and home ranges of four northern males and ICH, ESSF, and AT habitat types (*d*) in the SMGBE.



each individual bear. We did not pool data among bears because of high potential for bias and type 2 errors (White and Garrott 1990, pp. 188–191; Swihart and Slade 1997; Allredge et al. 1998). We report how many animals in the sample showed selection as recommended by Bart et al. (1998). We pooled location data among years for each bear because of small annual sample sizes for each bear (McLellan and Hovey 2001). Unlike McLellan and Hovey (2001), we did not analyze seasonal effects and reproductive status on bear use of roads because our smaller sample sizes would not allow such tests.

We collapsed the three habitat types into two broader types (low-elevation ICH, high-elevation ESSF and AT) to analyze road–habitat interactions because of too few observed and expected values in the AT (Wilkinson et al. 1992). We used similar DRCs (0–250, 251–500, >500 m) as McLellan and Shackleton (1988) to allow comparisons. These DRCs and habitat type categories allowed adequate sample sizes for testing (e.g., mean expected values >2, Roscoe and Byers 1971; <20% of cells with expected values <5, Wilkinson et al. 1992; Alldredge and Ratti 1986).

We tested for both type 2 (selection of home range) and type 3 (selection within home range) habitat selection (Johnson 1980; Thomas and Taylor 1990), because selection can occur at both levels (White and Garrott 1990). Type 2 expected values were calculated from the percentage of the southern or northern study area that covered each DRC, multiplied by the number of radiolocations within the southern or northern study area for each bear. We used radiolocations, not the proportion of the home ranges in each habitat type or road DRC because the proportional method assumes uniform use of the home range (White and Garrott 1990, p. 201), which was disproved by our type 3 analyses (see Results). Type 3 expected values were calculated from the percentage of a bears 100% multiannual, minimum area home range (Ackerman et al. 1990) that covered each habitat type or DRC, multiplied by the number of radiolocations for each bear. We conducted separate χ^2 analyses for habitat type and roads, using different minimum area home ranges for each analysis, because sample sizes were different between habitat and road data sets, and we did not wish to sacrifice statistical power by eliminating locations from the habitat data set.

We used χ^2 goodness of fit (Daniel 1978) and Bonferroni's *z* test (Neu et al. 1974) to test for selection. Empty cells were eliminated by adding a delta value of 0.5 to all cells (Wilkinson et al. 1992). Statistical significance ($P < 0.05$) was reported if the two methods yielded consistent results (Cherry 1996). Effects of habitat and road categories were presented as mean use/availability or selection ratios (Manly et al. 1993, pp. 9–11). We tested for differences in mean sample size (hence differences in statistical power) for bears in the southern (open and closed roads) and northern study areas (restricted roads) using the *t* test.

Confounding of road and habitat effects

We accounted for confounding of road and habitat effects using log–linear models (Feinberg 1980; Wilkinson et al. 1992). Our models consisted of three variables: habitat (H) with two categories (ICH and ESSF), roads (R) with three distance to road (DRC) categories (≤250, 251–500, >500 m), and usage (U) with two categories (used, available) in a 12-cell table. A significant U × R interaction indicated that used frequencies are different from available frequencies contingent on road DRCs. We conducted separate log–linear models for each road type (open, closed, restricted), because sample sizes were too small to analyze larger tables (i.e., 24 cells resulting from an open + closed road analysis). We used forward-selection modeling to see if adding the U × R interaction significantly improves the fit of the model after all other variables and interactions are accounted for (Knoke and Burke 1980). A small χ^2 log-likelihood improvement statistic ($P_i < 0.10$) indicates a significant improvement by fitting the U × R interaction. A large χ^2 log-likelihood goodness of fit statistic ($P_m > 0.10$) indicates the model fits the data (Fingleton 1987). We fitted all main effects: usage, habitat, and roads (model 1, U + H + R) and all other two-way interactions: (model 2, R × H; model 3, U × H) before testing for the U × R interaction as recommended by Knoke and Burke (1980). Models 4 (U + H + R + (R × H) + (U × R)) and 5 (U + H + R + (R × H) + (U × H) + (U × R)) tested for a usage by road interaction after accounting for a usage by habitat interaction. Statistical significance was set at $P \leq 0.10$, not 0.05 as in univariate χ^2 tests, because of the greater number of cells in this analysis (12 vs. 3), smaller samples per cell, and lower statistical power.

Results

Telemetry accuracy averaged approximately ±100 m. Seventeen percent of radiolocations were visually confirmed from the air, and 72% of site investigations (n = 311) had fresh grizzly bear sign (tracks, scats, digs, hairs) within 100 m of the estimated telemetry location.

We analyzed habitat use for 22 independent grizzly bears (Table 1) from 1986 to 1991. That sample accounts for approximately 50% of the estimated population size (U.S. Fish and Wildlife Service 1990). Bears were monitored for 3.13 ± 0.99 years (mean ± SD; n = 22). Each male was monitored for at least 2 years and 9 of 12 females for at least 3 years (3 females at 2 years each) to ensure unbiased variation in years and reproductive status for each bear. Sample sizes of locations for individual bears are given in Tables 1 and 2. There were no differences in mean radiolocation sample sizes between southern (44.8 ± 8.5; mean ± SE) and northern (48.5 ± 4.3) study areas (T = 0.39, 20 df, P = 0.70). Radiolocations were also relatively evenly distributed across years and months. There were 265 ± 114 (mean ± SD) radiolocations/year for 1986 to 1990 and 166 ± 64 radiolocations/month for April–November. We obtained a total of 1103 radiolocations for analysis of habitat type and 1027 radiolocations for analysis of roads and road × habitat interactions.

Use of habitat

In the south, 4 of 5 females and 4 of 6 males (8 of 11 bears) selected ($P < 0.05$) against the ICH and (or) for the ESSF habitat type (Table 1). Mean type 2 selection ratios for the ICH were 0.54 ± 0.10 (mean ± SE; n = 5) and 0.66 ± 0.07 (n = 6) for females and males. In the north, 6 of 7 females and 1 of 4 males (7 of 11 bears) selected ($P < 0.05$) against the ICH or for the ESSF habitat type. Mean type 2 selection ratios for the ICH were 0.45 ± 0.09 (n = 7) and 0.85 ± 0.08 (n = 4) for females and males. Most bears (16 of 22) selected against the ICH and selected for the ESSF habitat types.

Selection against the ICH occurred regardless of differences in road density. In the south, road densities for the ICH, ESSF, and AT zones were 1.5, 0.5, and 0.0 km/km^2. In the north, road densities were 0.8, 0.4, and 0.1 km/km^2. Road densities were almost twice as high in the southern vs. northern ICH, but selection ratios in the ICH were similar between areas. Road densities were similar in the ESSF and AT for southern and northern study areas.

Use of road types

In the south, 5 of 5 females and 4 of 6 males (9 of 11 bears) selected ($P < 0.05$) against open roads (Table 2). Mean type 2 selection ratios for the 0–250 m DRC were 0.36 ± 0.09 (n = 5) and 0.42 ± 0.09 (n = 6) for females and males. Both females and males selected against open roads. Four of 5 females and 0 of 6 males (4 of 11 bears) selected ($P < 0.05$) against closed roads. Mean type 3 selection ratios for the 0–250 m DRC were 0.51 ± 0.16 (n = 5) and 1.15 ± 0.19 (n = 6) for females and males. Only females selected against closed roads.

Table 1. Observed and expected (type 2 and 3) locations for grizzly bears in three different habitat types in the Selkirk Mountains Grizzly Bear Ecosystem.

		Type 2 locations			Type 3 locations		
Bear No.	*N*	ICH	ESSF	AT	ICH	ESSF	AT
Southern study area							
Females							
867	100	29/60*	68/37*	3/3	29/44*	68/55*	3/1
1015	65	16/39*	45/24*	4/2	16/29*	45/34*	4/2
1084	57	21/34*	30/21*	6/2	21/26	30/29	6/2
1087	68	36/41	32/25	0/2	36/38	32/30	0/0
1089	16	3/10*	13/6*	0/0	3/7	13/9	0/0
Males							
962	40	14/24*	26/15*	0/1	14/22*	26/18*	0/0
1004	71	23/35*	45/29*	3/7	23/28	45/39	3/4
1005	32	7/16*	18/13	7/3	7/10	18/19	7/3
1077	21	6/10	15/9*	0/2	6/8	15/11	0/2
1090	49	21/24	25/20	3/5	21/18	25/25	3/6
1091	35	14/17	19/14	2/4	14/8	19/21	2/6*
Northern study area							
Females							
1044	24	3/9*	14/11	7/4	3/5	14/12	7/7
1045	56	10/22*	34/25*	12/9	10/13	34/32	12/11
1047	30	2/12*	15/13	13/5*	2/6	15/16	13/8
1048	73	10/29*	48/33*	15/11	10/12	48/45	15/16
1056	63	24/25	27/28	12/10	24/18	27/32	12/13
1075	50	10/20*	31/23	9/7	10/16	31/26	9/9
1076	53	9/21*	30/24	14/8	9/8	30/32	14/12
Males							
1043	46	17/18	26/21	3/7	17/11	26/26	3/9*
1046	50	20/20	25/23	5/7	20/15	25/26	5/9
1057	48	14/23*	28/20	6/5	14/13	28/29	6/6
1078	56	20/23	20/25	16/8	20/10*	20/32*	16/14

Note: The first value is the observed value, and the second value is the expected value. Type 2 expected values are based on percent composition of southern and northern study areas for females and male 962, and entire study area for the remaining males. Type 3 expected values are based on percent composition of the home range of each bear.

*Observed number of locations is less than or greater than expected number at $P < 0.05$ ($\chi^2 = 5.99$, df = 2), using χ^2 goodness-of-fit followed by Bonferroni *z* tests.

In the north, 0 of 7 females and 0 of 4 males (0 of 11 bears) selected ($P < 0.05$) against restricted roads. Mean type 2 selection ratios for the 0–250 m DRC were 1.36 ± 0.19 ($n = 7$) and 1.27 ± 0.23 ($n = 4$) for females and males. Mean type 3 selection ratios for the 0–250 m DRC were 0.89 ± 0.09 ($n = 7$) and 0.91 ± 0.15 ($n = 4$) for females and males. Neither females nor males selected against restricted roads.

Confounding between roads and habitat

Open roads

Four of five females that selected against open roads (Table 2) still selected ($P < 0.10$) against these roads after accounting for habitat (Table 3), so open roads had a negative effect on females (more than one-half of female bears selected against open roads). Three of four males that selected against open roads still selected against these roads after accounting for habitat, so open roads had a negative effect on males (one-half of male bears selected against open roads).

Closed roads

Three of four females that selected against closed roads still selected ($P < 0.10$) against these roads after accounting for habitat, so closed roads had a negative effect on females (more than one-half of female bears selected against closed roads). No males selected against closed roads after accounting for habitat effects, so closed roads had no apparent negative effect on males.

Restricted roads

No females or males selected against restricted roads after accounting for habitat effects, so restricted roads had no apparent negative effect on bears.

Discussion

Males and females in both study areas selected against the ICH and selected for ESSF. This seems unlikely simply because of higher road densities in the ICH than in the ESSF because bears in the north did not select against roads, but they did select against the ICH. Furthermore, selection ratios

Table 2. Observed and expected (type 2 and 3) locations for grizzly bears in three distance to road categories in the Selkirk Mountains Grizzly Bear Ecosystem.

		Type 2 locations			Type 3 locations		
Bear No.	*N*	0–250 m	251–500 m	>500 m	0–250 m	251–500 m	>500 m
Open roads							
Females							
867	100	3/22*	3/13*	94/65*	3/11*	3/7	94/82*
1015	65	4/14*	6/8	55/42*	4/10	6/6	55/49
1084	57	6/13*	3/7*	48/37*	6/9	3/5	48/43
1087	68	10/15	3/9*	55/44*	10/13	3/7	55/47
1089	16	0/4*	1/2	15/10*	0/3	1/2	15/12
Males							
962	40	3/9*	2/5*	35/26*	3/6	2/4	35/30
1004	65	4/14*	4/8	57/42*	4/12*	4/8	57/45*
1005	14	1/3	2/2	11/9	1/3	2/2	11/10
1077	20	0/4*	1/3*	19/13*	0/4*	1/2	19/14*
1090	28	5/6	3/4	20/18	5/5	3/3	20/19
1091	20	2/4*	0/3*	18/13*	2/5*	0/3*	18/11*
Closed roads							
Females							
867	100	30/16*	16/7	54/76	30/42*	16/14	54/44
1015	65	4/11	4/5	57/50	4/18*	4/6	57/41*
1084	57	5/9	6/4	46/44	5/16*	6/7	46/34*
1087	68	26/11*	13/5*	29/52*	26/24	13/9	29/35
1089	16	1/3*	4/1*	11/12	1/4	4/2	11/9
Males							
962	40	16/6*	7/3	17/31*	16/16	7/6	17/19
1004	65	16/11	7/5	42/50	16/15	7/6	42/43
1005	14	5/2	2/1	7/11	5/3	2/1	7/10
1077	20	2/3	2/1	16/15	2/6	2/2	16/12
1090	28	4/5	0/2	24/21	4/3	0/1	24/24
1091	20	3/3	0/1	17/15	3/2	0/1	17/18
Restricted roads							
Females							
1044	24	6/4	4/3	14/17	6/6	4/4	14/14
1045	53	17/10	4/6	32/37	17/14	4/8	32/31
1047	30	5/6	2/3	23/21	5/8	2/5	23/17
1048	73	17/13	13/8	43/51	17/18	13/12	43/43
1056	63	15/12	5/7	43/44	15/19	5/10	43/34
1075	50	7/9	7/6	36/35	7/12	7/8	36/31
1076	53	22/10*	9/6	22/37*	22/20	9/10	22/23
Males							
1043	46	12/8	5/5	29/32	12/14	5/8	29/24
1046	50	14/9	4/6	32/35	14/12	4/7	32/32
1057	36	10/7	12/4*	14/25*	10/9	12/6*	14/21*
1078	56	6/10	7/6	43/39	6/12	7/8	43/36

Note: The first value is the observed value, and the second value is the expected value. Type 2 expected values are based on percent composition of southern and northern study areas. Type 3 expected values are based on percent composition of home ranges for each bear.

*Observed number of locations is less than or greater than expected number at $P < 0.05$ ($\chi^2 = 5.99$, df = 2) using χ^2 goodness-of-fit followed by Bonferroni *z* tests.

against the ICH were similar between the south and north despite differences in road density. The reasons for selection against the ICH are unknown but may be related to food supply. The ESSF appeared to have an abundance of bear foods relative to the ICH (R.B. Wielgus, unpublished data). Similar selection by grizzly bears against lower elevations (<1500 m) were reported by Wielgus and Bunnell (1994) and Mace et al. (1999). The results from this and other studies suggest that factors other than roads (e.g., relatively poor food supply) may influence selection against some low-elevation habitat types in some areas by bears. Our results do not support the hypotheses that grizzly bears select against open, restricted, and closed roads in that order. We are confident in our test results that males and females selected against open roads and that females selected against closed roads, despite our small radiolocation sample sizes,

Table 3. Best log–linear models based on log-likelihood goodness of fit χ^2 probabilities (P_m) and improvement χ^2 probabilities (P_i) for type 2 and type 3 grizzly bear selection of open, closed, and restricted road corridors in the Selkirk Mountains Grizzly Bear Ecosystem.

	Type 2			Type 3		
Bear No.	Best model*	P_m	P_i	Best model	P_m	P_i
Open roads						
Females						
867	5†	0.23	0.00	5†	0.27	0.07
1015	3	0.72	0.00	3	0.74	0.01
1084	4†	0.37	0.03	2	0.83	0.00
1087	4†	0.56	0.05	2	0.41	0.00
1089	5†	1.00	0.11	2	0.33	0.01
Males						
962	3	0.50	0.00	3	0.70	0.05
1004	5†	0.62	0.07	4†	0.62	0.04
1005	1	0.22	0.00	1	0.62	0.00
1077	5†	0.53	0.02	4†	0.75	0.02
1090	3	0.96	0.06	2	0.85	0.02
1091	4†	0.35	0.03	4†	0.64	0.03
Closed roads						
Females						
867	5†	0.11	0.00	3	0.56	0.02
1015	3	0.23	0.00	5†	0.08	0.00
1084	3	0.04	0.01	4†	0.04	0.01
1087	5†	0.68	0.00	2	0.68	0.00
1089	5†	0.84	0.05	2	0.33	0.06
Males						
962	5†	0.46	0.00	3	0.65	0.03
1004	5†	0.69	0.04	2	0.87	0.17
1005	5†	0.69	0.07	1	0.44	0.00
1077	3	0.72	0.03	2	0.31	0.04
1090	1	0.33	0.00	1	0.63	0.00
1091	3	0.43	0.03	1	0.48	0.00
Restricted roads						
Females						
1044	3	0.76	0.04	2	0.81	0.11
1045	3	0.26	0.00	2	0.70	0.01
1047	3	0.97	0.00	3	0.91	0.00
1048	3	0.30	0.00	2	0.89	0.00
1056	1	0.24	0.00	1	0.16	0.00
1075	3	0.98	0.00	3	0.87	0.06
1076	5†	0.13	0.00	2	0.67	0.00
Males						
1043	1	0.79	0.00	3	0.61	0.07
1046	2	0.76	0.04	4†	0.52	0.02
1057	5†	0.54	0.00	5†	0.89	0.01
1078	2	0.18	0.00	5†	0.63	0.03

*Model 1, U + H + R; model 2, U + H + R + (R × H); model 3, U + H + R + (R × H) + (U × H); model 4, U + H + R + (R × H) + (U × R); model 5, U + H + R + (R × H) + (U × H) + (U × R).

†Indicates significant road effects after accounting for effects of habitat type (see text).

because small samples result in increased type 2 not type 1 errors (Sokal and Rolf 1981). We are also confident in our test results that neither males nor females selected against restricted roads, because location sample sizes (hence statistical power) were not smaller than in open and closed road areas where selection was observed. Finally, we monitored approximately 50% of the estimated grizzly bear population, and this large proportion should be representative of bears in the area.

As expected, both female and male grizzly bears did select against open roads. Most females showed type 2 (within study area) but not type 3 (within home range) selection against open roads, probably because selection against open roads already occurred at the type 2 level. Males showed both type 2 and 3 selection against open roads, possibly because they had larger home ranges than females (Figs. 1*a* and 1*d*), making their type 2 and 3 availabilities similar (Table 2). Selection against open roads by females in the south was consistent with results in Montana (Kasworm and Manley 1990; Mace et al. 1996). However, in those study areas, bears selected against areas <900 m and <500 m from open roads. In our study area females only selected against areas <250 m of a road. It could be that denser forests in the SMGBE ameliorate the effects of roads. Archibald et al. (1987), working in the dense coastal forests of British Columbia, also found that selection against roads by females disappeared after 300 m. McLellan and Shackleton (1988), working in the Flathead Valley of British Columbia, found that bears selected against areas only <100 m from roads. The selection against open roads by males in the south is also consistent with findings by Mattson et al. (1987) in Yellowstone and McLellan and Shackleton (1988) in the Flathead Valley of British Columbia. They also found that male bears selected against open roads.

As expected, males did not select against closed roads. However, contrary to expectations, female grizzly bears selected against closed roads. Females tended to show type 3 but not type 2 selection against closed roads. This follows from their type 2 selection against open roads. Females may first choose their home range area based on a paucity of open roads, then select against closed roads within the resulting home range.

Female avoidance of closed roads due to avoidance of males near those roads is unlikely, since sexual segregation and avoidance of males was not observed in this area (Wielgus and Bunnell 1995). Our results are similar to Mace et al. (1999). They also found that females selected against closed roads but that the intensity of selection was less than that of open roads. We suspect that females would not select against closed roads had they not been intermixed with open roads (see next paragraph). Also contrary to expectations, both female and male grizzly bears did not select against restricted roads. We cannot compare these results with other studies, since no other researchers have examined the effects of restricted roads on bears.

Based on these results, we suggest that the type and level of human activity on roads (and proximity to open roads) may determine whether a road type is selected against or not. For example, human use appeared higher on restricted than on closed roads; yet, bears did not select against restricted roads but did against open and closed roads. Open roads were used by hunters, fishers, hikers, berry pickers, and other forest users as well as forestry workers. These forest users frequently stopped their vehicles and wandered off the roadway. By contrast, restricted roads were used by forestry workers that rarely left their vehicles and the roadway. Most of their off-road activity was restricted to well-defined cutting units where forest harvesting and silviculture was taking place. In a similar area, grizzly bears reacted more strongly to people on foot than in vehicles (McLellan and Shackleton 1989*a*), and this could explain, in part, bear selection against open roads and their lack of selection against restricted roads.

Perhaps more importantly, the core of the restricted road area was privately owned in Canada and hunting of any species was strictly prohibited there. As a result, no bears were known to be killed recently by humans there. Grizzly bears may have learned that forestry traffic on these restricted roads had no negative consequences for them, and they may have habituated to these roads. Similar habituation to industrial activity on roads was reported by McLellan and Shackleton (1989*a*, 1989*b*). By contrast, all known human-caused mortalities of bears in the SMGBE occurred on or near open roads in the United States and the Canadian southern study area, and in this area, shooting deaths accounted for the bulk of all mortalities (Wielgus et al. 1994). By being shot at, wounded, or witnessing shootings near roads, bears may have learned to avoid open roads. Furthermore, bears that did not select against open roads may have been killed, resulting in a population that tends to select against roads (Mattson et al. 1996).

We interpret the selection against closed roads by females as cautious behavior. Because open roads are in relatively close proximity to closed roads and within bear home ranges (Figs. 1*a* and 1*b*), female bears may have failed to discriminate between open and closed roads. However, males in the south did appear to discriminate between road types. We suspect that females were more security conscious than males and could have viewed closed roads similarly to adjacent open roads (e.g., as potential hazards to themselves and their offspring).

Management implications

Our findings suggest that cessation of all forestry activities in grizzly occupied areas may not be necessary to maintain habitat effectiveness. Bears did not select against restricted roads, and no bears were shot from restricted roads on these private lands. It appears that exclusive forestry use of roads had no apparent negative impact on bears, at least in the heavily forested SMGBE. Partial or piece-meal road closures such as by the USDA Forest Service in the SMGBE may not be as effective as previously thought. Such road closures will reduce mortalities along the roadway, but female bears may still avoid closed roads and adjacent habitats if they are exposed to open roads within their home ranges. Whether selection against open roads and associated habitat loss translates to reduced reproduction and negative population growth is unknown at present. However, it is clear that open roads result in habitat avoidance and loss (this study) and increased mortality (Wielgus et al. 1994). We recommend that open roads in grizzly occupied areas be restricted to forestry use only whenever possible.

Our interpretations and recommendations require cautious caveats because of small sample size, lack of experimental replication, and because we could not assess potential effects of season and reproductive status on selection of road DRCs. It could be that certain reproductive classes of females (e.g., with cubs) select against restricted roads during certain seasons (e.g., spring, early summer), but we could not test for such effects because of sample size limitations (see Methods). We encourage other researchers in other areas to replicate our study to increase experimental sample size.

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