GRIZZLY BEAR MORTALITY AND HUMAN ACCESS IN BANFF AND YOHO NATIONAL PARKS, 1971–98

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Abstract: We conducted spatial and temporal analyses to examine the relationship between access, changing grizzly bear management strategies, and grizzly bear (*Ursus arctos*) mortality for 1971–98 in Banff and Yoho National Parks, Canada. We summarized mortality by cause of death, sex, age, and cohort. The annual number of grizzly bear deaths declined significantly between 1971–84 and 1985–98. However, the female portion of this mortality was 80% from 1985–98 compared to 50% during the earlier period. Human-related causes were the primary sources of recorded grizzly bear mortality in the study area (119 of 131 known mortalities). Control of problem bears accounted for 71% of 119 known human-caused mortalities, followed by highway and railway mortalities (19%), unknown cause of death (9%), and research (<1%). All 95 human-caused mortalities with known accurate locations were within 500 m of roads or 200 m of trails. Eighty percent of these mortalities occurred below 2000 m. Kills were concentrated at Banff townsite, Lake Louise, and along the Trans Canada Highway. Management of development, trail access, and human food and garbage are critical for managing grizzly bear mortality in the national parks. We present specific recommendations.

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Key words: access, Banff National Park, Canada, development, grizzly bear, mortality, *Ursus arctos*, Yoho National Park, zone of influence

Grizzly bears in Banff and Yoho National Parks are part of a regional ecosystem in Canada called the Central Rockies Ecosystem (Fig. 1). The Central Rockies Ecosystem is experiencing intensive exploration and development of coal, oil, gas, and timber reserves. Cattle production, housing and highway development, and outdoor recreation are also increasing. Moreover, present attitudes toward the grizzly bear, a potentially dangerous animal (Herrero 1985) and competitor with humans for food and space (Mattson 1990), challenge human–grizzly bear coexistence. As a result, the grizzly bear is suffering from continuing habitat degradation and potentially unsustainable mortality rates in some regions of the Central Rockies Ecosystem (Herrero et al. 2000).

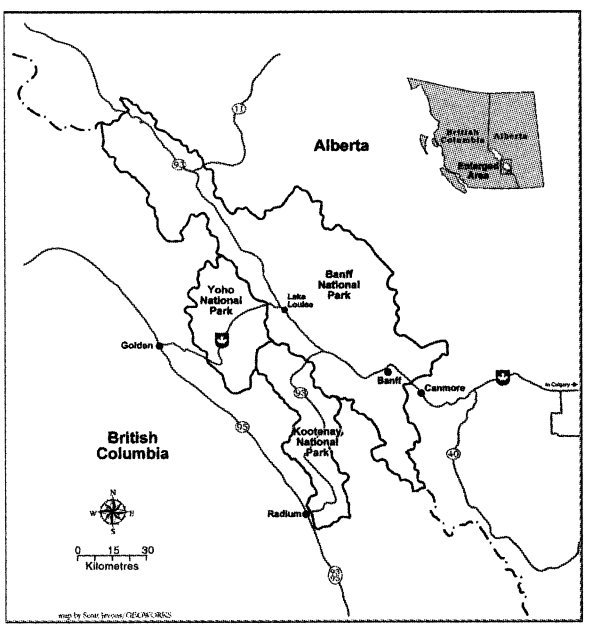

Fig. 1. The National Parks of the Central Rockies Ecosystem.

The national park portions of the Central Rockies Ecosystem continue to experience increases in human use, commercial development, and major transportation expansion with the doubling of the number of lanes of the Trans Canada Highway through Banff National Park (Banff-Bow Valley Study 1996). Grizzly bear hunting occurs on most provincial lands surrounding the parks. Interagency planning for effective land use at the regional scale (Herrero 1994), whereby bears can meet their energetic requirements and encounters between humans and bears can be reduced, may be the best option for reducing grizzly bear mortality (Mattson and Knight 1991).

Natural survival rates for adult grizzly bears in unhunted populations are high and consistent (Knight and Eberhardt 1985, McLellan 1990), whereas young bears die more frequently of natural causes such as intraspecific aggression (Stringham 1983), accidents (Nagy et al. 1983), and nutrition related causes (Nagy et al. 1983, Knight et al. 1988). However, tracking natural mortality is very difficult because habitat is often remote and heavily forested and carcasses are soon scavenged. Nonetheless, natural mortality is probably a minor cause of adult mortality (McLellan et al. 1999). Mortality data from North America show that human-caused mortality far outnumbers natural mortality (Craighead et al. 1988, McLellan 1990, Dood and Pac 1993, Gunson 1995). Historical (Storer and Tevis 1955, Noble 1972, McCrory and Herrero 1982) and recent works (McLellan and Shackleton 1988*a*, Mattson et al. 1996) consistently link the type and degree of human land use with grizzly bear mortality.

Sustainable total and harvest mortality rates for bears have been estimated in computer-simulated populations (Bunnell and Tait 1980, Harris 1986). However, the threshold mortality rate where grizzly bear populations begin to decline can rarely be determined precisely. The

determination of population numbers and vital rates for grizzly bears requires long term study, and the number of undetected mortalities is typically estimated by inference. McLellan et al. (1999) used unreported mortality of radiocollared bears from various western cordilleran studies to estimate the percentage of unreported human-caused mortality. They found that management agencies would have only detected 45–51% of human-caused mortality of radiocollared grizzly bears.

Roads are frequently implicated in contributing to increased grizzly bear mortality. They facilitate access for a host of human activities, increase the frequency of energetically costly flight responses, and increase vehicle related mortalities (Mattson et al. 1987, Nagy et al. 1989, Gibeau et al. 1996). As well, roadside vegetation may attract bears to roads, compounding the risk. At some undetermined level of human use, grizzlies, in particular established adult females, cease crossing major transportation corridors (Gibeau and Herrero 1998).

We analyzed grizzly bear mortality for Banff and Yoho National Parks for 1971–98. Results are discussed before and after changes in grizzly bear management strategies and relative to access.

STUDY AREA

The study area was Banff (6,836 km^2) and Yoho national parks (1,313 km^2) (Fig. 1). The vegetation and climate for the entire Central Rockies Ecosystem was described in Benn (1998). Major transportation corridors dissect both national parks. Approximately 58% (4,726 km^2) of the study area is suitable grizzly bear habitat (<2,400 m), above which there is little grizzly bear foraging (Gibeau et al. 2001). Thus, grizzly bear habitat is restricted to major vegetated valley systems. Human use is also concentrated in these valleys. Zones of human influence around trails, roads, and other developments occupy about 25% of the suitable habitat (Gibeau et al. 2001). Grizzly bear population estimates for Banff National Park were 55–85 (G.W. Vroom, 1974, Grizzly and wolf observations, Banff National Park, Banff, Alberta, Canada) and 60–80 (Gibeau et al. 1996).

METHODS

Mortality and translocation databases for grizzly bears were supplied by Banff and Yoho National Parks for 1971–98. Additional mortality records came from other wildlife files provided by Parks Canada Western Region Office, annual warden and superintendent reports, a consultant's report (Millson 1978), and several graduate theses (Noble 1972, Taylor 1984). Mortalities included dead bears, bears translocated to remote areas north and west of the parks that were not known to have returned, translocated bears that died in other jurisdictions, and bears placed in zoos. We used these mortality data to summarize mortality by cause, sex, age, and cohort.

Spatial Analyses

Locations of bear mortalities were referenced to the universal transverse Mercator (UTM) grid to the nearest 100 m and included a descriptor such as a river, creek, or cultural feature. Interviews were conducted with past and present wardens and wildlife managers to collect additional information about specific mortalities and their locations. We classified locations as accurate, reasonable, and estimate. Accurate locations had a UTM designation to ±100 m and a geographic descriptor. Reasonable locations were within some stated distance from a known road, trail, drainage, or development. Mortalities with estimated locations were excluded.

Digital data containing human access information at a scale of 1:50,000 were supplied by Parks Canada. The road layer included railway lines and roads open to the public and negotiable by 2-wheel drive vehicle. The trail layer included roads closed to the public, utility corridors, and any other linear access features accessible by hiking, mountain biking, or horseback.

Access and mortality data were entered into a geographic information system, MapInfo 4.0 (MapInfo Corporation, Troy, New York, USA). Zones of influence (ZOI) of 500 m and 200 m were set around roads and trails, respectively, based on the judgment of the authors. Buffer widths of 500 m for motorized roads and 300 m for non-motorized trails were used in the cumulative effects model for grizzly bear in Yellowstone National Park (Mattson 1999). The Central Rockies Ecosystem has steeper and narrower valleys than Yellowstone, thus we are comfortable with 200 m for non-motorized trails in this forested mountain landscape. Road and trail buffers were combined into a single coverage and the area of overlap was only calculated once. Mortality locations in the area of overlap were analyzed as occurring within road buffers because roads were assumed to have a greater effect on mortality risk than trails.

Mortalities were tallied with respect to proximity to townsites and commercial tourist operations. We assumed that bears were attracted to these areas by the presence of food and garbage (Mattson et al. 1987, Weaver et al. 1987). This assumption was supported by limited data from mortality records and discussions with bear managers.

We recorded the elevation of 95 human-caused grizzly bear mortality locations and the elevations of some tourist destinations and park developments.

Temporal Analyses

We stratified mortality data into 2 periods to relate changes in mortality characteristics with changing patterns of human use and evolving management concerns and actions. We chose 1984–85 as the break, although no major changes occurred in any single year. Rather, a series of events in the early 1980s led to a progressive modification in management practices. These events included (1) the 1980 Whiskey Creek bear maulings in Banff National Park (A. Westhaver and A. Williams, 1980, Report of the superintendent's review team on the bear mauling incidents, Banff National Park, Resource Conservation and Interpretive Service, Banff, Alberta, Canada; Herrero 1985), which stimulated improved garbage management and increased efforts at communication and public education with respect to bears, (2) closure of the Banff landfill in 1981, and (3) commencement of fencing of the Trans Canada Highway from Banff's east park gate in 1983. Also, we recognized that it would take a few years for the bear population to adapt behaviorally to events such as the landfill closure. Finally, for ease of comparison, these periods were of equal length (1971–84, 1985–98). The Mann-Whitney *U*-test was used to test for differences in the annual number of grizzly bear deaths between periods, with $\alpha = 0.05$. The following hypotheses were tested:

- H_{o1}: The annual number of grizzly bear mortalities in Banff and Yoho National Parks did not decline significantly from 1971–84 to 1985–98.
- H_{o2}: The annual number of problem grizzly bear mortalities in Banff and Yoho National Parks did not decline significantly from 1971–84 to 1985–98.

Finally, we analyzed cause of death by seasons. We used 3 seasons of importance to bears (Apr–Jul = preberry, Jul–Oct = berry, Oct–Dec = post-berry).

RESULTS

We collected 108 and 11 records of human-caused mortality from Banff and Yoho National Parks, respectively. The average annual mortality was 4.3 grizzly bears/year, with peaks of 15 recorded deaths in 1972 and 13 in 1980 (Fig. 2).

Management actions and vehicle and train collisions accounted for 71% and 19%, respectively, of the 119 human-caused grizzly bear deaths. The remaining 10% included 1 research related incident and 11 deaths from unknown causes. In addition to mortalities recorded within Banff and Yoho National Parks, at least 7 research grizzlies known to use Banff and Yoho National Parks were killed in British Columbia and Alberta (M.L. Gibeau and S. Herrero, 1998, Eastern Slopes Grizzly Bear Project, Year 4-1997, Progress Report for the Eastern Slopes Grizzly Bear Project Steering Committee, Calgary, Alberta, Canada). We knew the sex and age of 83 dead grizzly bears (Table 1). Adult females and dependent young (cubs-of-the-year and yearlings) accounted for 65% of this total. Females accounted for 51% of all mortalities of known sex since 1971 (Table 1), and even after closure of the Banff landfill in 1981, 18 of 22 bear mortalities with sex known were female (Fig. 3). An additional 11 mortalities were unclassified as to sex during this time.

Of 85 problem wildlife mortalities, 64.7% were destroyed and 35.3% were handled for translocation purposes. Fifteen of the grizzlies handled died accidentally, and 15 were translocated. Five of the translocated bears were placed in the Calgary Zoo and 5 died in Alberta within 1–2 years of capture (1 shot legally, 2 shot illegally, 1 problem wildlife, 1 unknown cause).

Eleven family groups consisting of at least 6 cubs-of-the-year and 10 yearlings were destroyed or translocated

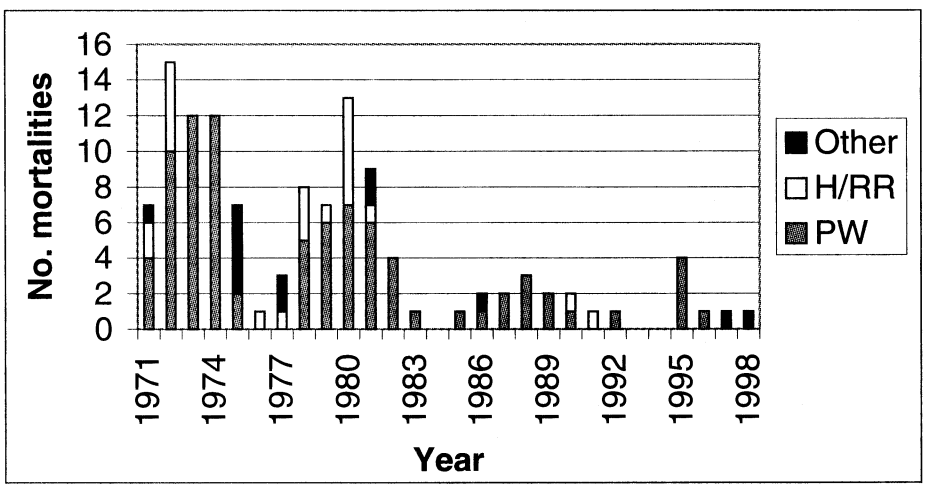

Fig. 2. Annual human-caused grizzly bear mortalities by type for Banff and Yoho National Parks, 1971—98, (*n* = 119). PW = problem wildlife, H/RR = highway/railway, Other = research or unknown.

Table 1. Percent grizzly bear mortality (number) by sex, age, and cohort for Banff and Yoho National Parks, 1971–98 (n = 119).

Sex		Age		Cohort	
male	33.9 (40)	adult	34.7 (41)	dependent	29.4 (35)
female	35.3 (42)	dependent	29.7 (35)	adult female	16.0 (19)
unknown	31.1 (37)	subadult	12.7 (16)	adult male	15.1 (18)
		unknown	22.9 (27)	subadult female	7.6 (9)
				subadult male	1.7 (2)
				unknown	30.3 (36)

from the ecosystem. This was considered a minimum number as 69% of 64 recorded problem wildlife mortalities were adult females (17) and dependent (cubs-of-the-year or yearlings) bears (27). Twenty-one records had no sex or age attached. Of 15 vehicle and train collisions where the cohort was known, adult males accounted for 47%, dependent bears 33%, and adult and subadult females 20%.

Spatial Analyses

All 95 human-caused grizzly bear mortalities, classified as having accurate or reasonable locations, occurred within zones of influence along roads and trails or around human settlements (Fig. 4). Mortality concentrations occurred at Banff and Lake Louise townsites and along the Trans Canada Highway (Table 2). A minimum of 59 mortalities throughout the analysis period was associated with the presence of human food and garbage.

Eighty percent of all known mortality locations were below 1,800 m. The remaining 20% occurred at 1,800–2,100 m (Fig. 5).

Temporal Analyses

We rejected both Hypotheses 1 and 2. The mean annual number of mortalities declined significantly from 1971–84 ($\bar{x}$ = 7.07) to 1985–98 ($\bar{x}$ = 1.43; U = 164.5, P = 0.0010). The mean annual number of problem wildlife mortalities also declined significantly from 1971–84 ($\bar{x}$ = 4.93) to 1985–98 ($\bar{x}$ = 1.14; U = 151.0, P = 0.0066).

Most mortalities in both periods were problem bears (67% during 1971–84; 80% during 1985–98). Although the number of problem bear deaths declined during 1985–98, the percentage of females increased from 50% to 80%. Adult females and dependent bears (cubs-of-the-year and yearlings) increased from 66% of the total mortality in the early period to 79% during period 2. Only 2 of 22 highway and railway mortalities occurred in the latter period.

We knew the date of death in 72 instances. More deaths (57%) occurred during the berry season (mid-Jul–late Sep) than during the pre-berry (35%) and post-berry (8%) seasons. Seventy-five percent and 58% of 48 dated mortalities of problem bears occurred during the peak tourist

Table 2. Types of developments and land uses where human-caused grizzly bear mortalities occurred in Banff and Yoho National Parks, 1971–98 (n = 95; some sites are tallied twice so total is >95).

Location of kill	No.	Detail of location
highway/railway	22	Trans Canada (16), Banff-Jasper (2), other (1), railway (3)
townsite	27	Lake Louise (15), Chateau Lake Louise (7), Banff (2), Field (3)
garbage dump/landfill	19	Banff (15), Lake Louise (4)
campground	16	
ski resort	8	Lake Louise (3), Norquay (3), Sunshine (2)
commercial lodge	11	
warden cabin	3	

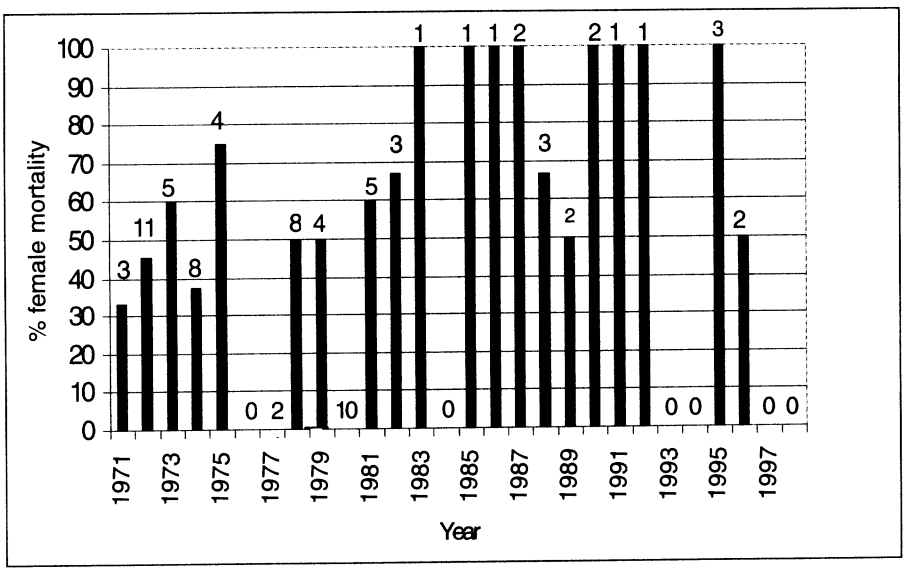

Fig. 3. Percent females in annual grizzly bear mortality. Numbers above the bars are the total mortalities with sex known for that year.

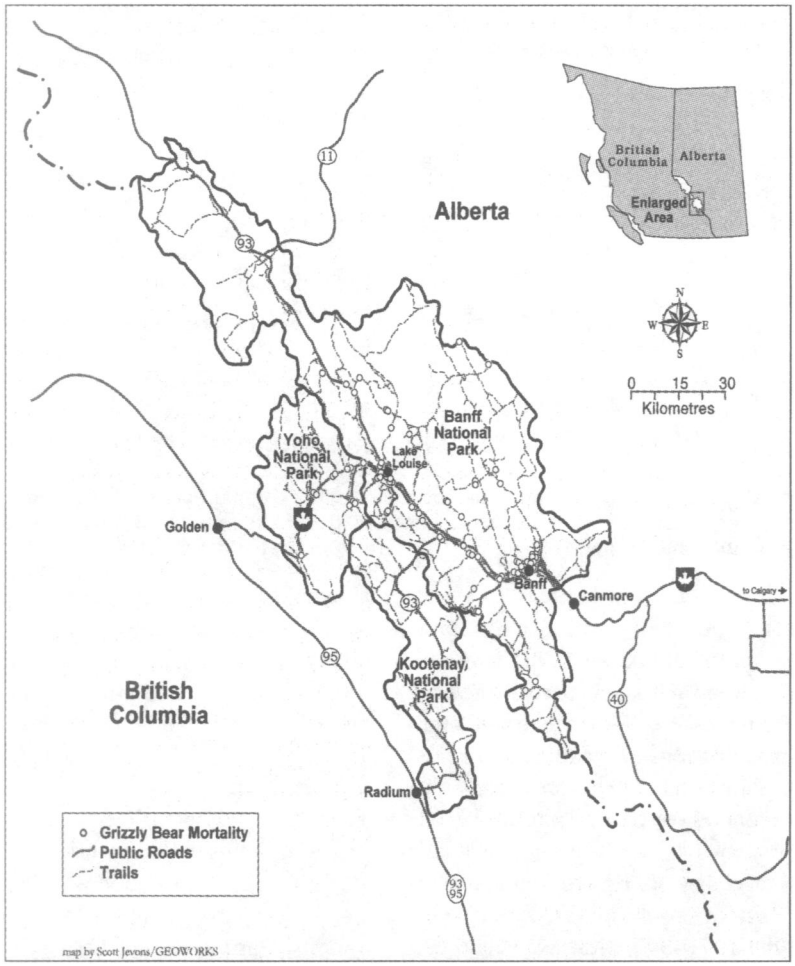

Fig. 4. Grizzly bear mortality locations in relation to roads and trails in Banff and Yoho National Parks, 1971–98.

season (late Jun–early Sep) and during the berry season, respectively.

DISCUSSION

The 119 recorded human-caused grizzly bear deaths in Banff and Yoho National Parks were considered to be the minimum number from 1971–98. Past and present wildlife managers suggested that there were probably more mortalities than were recorded, particularly during the 1970s (R. Kunelius, Banff National Park, Alberta, Canada, personal communication, 1998; M. Gibeau, Eastern Slopes Grizzly Bear Project, University of Calgary, Alberta, Canada, personal communication, 1998; D. Poll, Parks Canada, Western Region Office, Calgary, Alberta, Canada, personal communication, 1998). This large number of deaths caused by humans contrasts strongly with the adjacent and larger Jasper National Park, where in 1975–98 there were only 39 known grizzly bear mortalities (W. Bradford, Wildlife Warden, Jasper National Park, Alberta, Canada, personal communication, 1999).

Problem bear mortality was the most significant cause of death for this study. Management interventions helped reduce the total number of deaths (male and female) in 1985–98. However, the percent of female mortalities during this period increased from 50% to 80%, and the average annual female mortality was still higher than the total human-caused mortality target set based on the park's population estimate. This human-caused female mortality is the highest percent of total human-caused mortality reported for over 10 years for any grizzly bear population. As well, the human-caused mortality of dependent bears (cubs-of-the-year or yearlings) remained high throughout the study. These results may be explained by changing habitat use by specific cohorts over time. The higher male mortality in the early period was probably the result of more male bears feeding closer to people (in landfills and unsanitary campgrounds, Noble 1972). With the landfill closures and improved camper attitudes and garbage management, adult males may have selected habitats remote from human activity zones. Subadult grizzlies and adult females with young may have been more

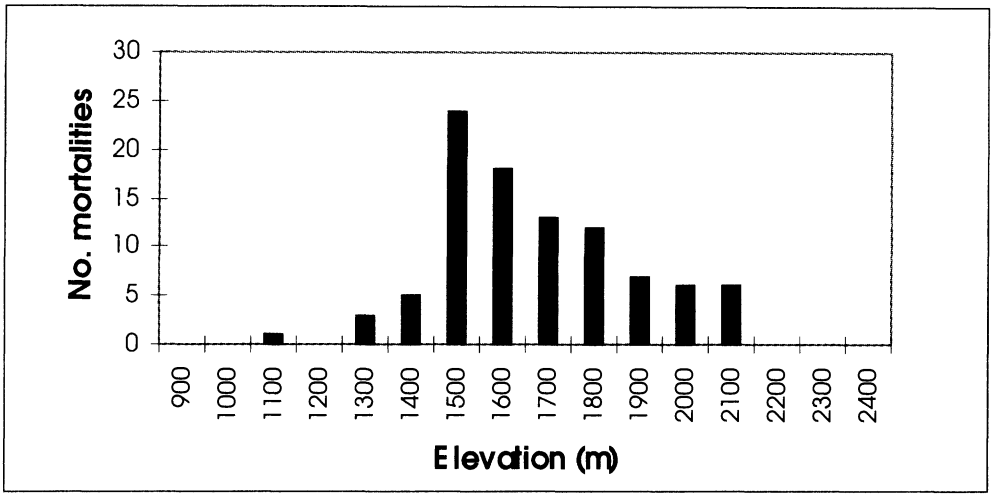

Fig. 5. Grizzly bear mortality locations by elevation in Banff and Yoho National Parks, 1971–98 (n = 95). Elevations of high human use areas in the parks: Banff, 1375 m; Castle Junction, 1430 m; Lake Louise, 1540 m; Chateau Lake Louise, 1740 m; Skoki Lodge, 2135 m; Moraine Lake Lodge, 1900 m; Lake O'Hara, 2000 m; Field, BC, 1250 m.

likely to use habitats near people, presumably to avoid adult males (Mattson et al. 1992, Gibeau et al. 1996). Thus, they may have been prone to habituation to humans and attraction to human food and garbage, increasing their mortality risk relative to males (Fig. 3) and their potential to be destroyed or translocated as problem animals (Mattson et al. 1987). This dynamic was previously described for the Yellowstone Ecosystem (Craighead et al. 1995).

The high accidental mortality of bears during management actions was the result of several points. All of these incidents occurred in the 1971–84 period. At this time, managers had less experience with tranquilizing drugs and handling techniques, and attitudes differed regarding animal welfare and grizzly bear conservation. We believe that all of these factors have improved in recent years.

Road mortality declined during 1985–98 even though traffic volumes increased. We have no definitive data to explain this; however, one likely cause is that the highway was fenced in stages to keep wildlife off the highway. Also, traffic became distributed over a 24-hour period and may have become so continuous as to act as a barrier to bears crossing unfenced portions of the corridor.

We found that grizzly bears died at low elevations and near human settlements and access. Roads, trails, and developments are almost always placed in valley bottoms, often fragmenting riparian habitats. Similarly, concentrations of kills at settlements and along roads and trails occurred throughout the Central Rockies Ecosystem (Benn 1998) and in other grizzly bear populations (Mattson et al. 1987, Nagy et al. 1989, Mace et al. 1996). Gibeau et al. (2001) showed that human use and developments reduced the amount of secure habitat for grizzly bears. Roads and trails improve access, and when placed in important seasonal habitats, increase the potential for negative bear–human encounters (McLellan and Shackleton 1988*b*). Increased access to the backcountry has been shown to alter bear behavior (McCullough 1982, Jope 1985), increase bear–human conflicts (Dalle-Molle and Van Horn 1989), increase the number of grizzly bear removals (Martinka 1982, Leonard et al. 1990), and displace certain cohorts, such as females with young (Mattson et al. 1987, Gilbert 1989).

The abrupt decline in grizzly bear mortality into the mid 1980s was correlated with closing the Banff landfill, improving garbage management, increasing public education regarding living and recreating in bear country, improving tolerance of grizzly bears, fencing of the Trans Canada Highway, and increasing use of aversive conditioning techniques over removals. However, the high mortality rate of the early period may have depressed the park's grizzly bear population. This effect could have continued through the 1985–98 period due to a lag effect and mortality concentrated in the female cohort. Closures of Yellowstone National Park landfills were followed by sharp declines in reproductive and survival rates (Craighead et al. 1974).

Finally, we found that a high proportion of mortalities occurred during the berry season. In mid-July to early October, grizzlies in the Central Rockies Ecosystem feed primarily on buffaloberry (*Shepherdia canadensis*) at lower elevation, often along roads and near people.

Human intolerance, inadequate management of access and food attractants, and a high rate of commercial development continue to be important contributing factors to grizzly bear mortality in Banff National Park. However, specific steps have been taken to reduce human-caused grizzly bear mortality. Recommendations by the Eastern Slopes Grizzly Bear Project to the Banff-Bow Valley Task Force (Gibeau et al. 1996) led to the implementation of

an annual human-caused mortality target of <1% of the estimated grizzly bear population. Also, habitat effectiveness targets aimed at supporting grizzly bear habitat use have been set for most carnivore management units. By implementing measures aimed at reducing potential conflicts between humans and grizzlies, human-caused grizzly bear mortality and the potential for human injury can be reduced.

There is an urgent need for these measures to be successful in the national parks and the rest of the Central Rockies Ecosystem. Because precise measurements of population demographic rates are only now becoming available, management of mortality must be conservative and management plans must consider adjacent jurisdictions in Alberta and British Columbia (Herrero et al. 1998). A recent population and habitat viability assessment workshop predicted both population and habitat declines for grizzly bears in the Central Rockies Ecosystem (Herrero et al. 2000). Because Banff and Yoho national parks are assumed to serve as core refugia for sensitive species such as grizzly bears, and because grizzly bear hunting exists on most of the land surrounding these national parks, human-caused mortality inside the parks must be minimal. Ecological integrity is the stated priority of the national parks (Banff National Park 1997), and the grizzly bear serves as the premier indicator of the health of the terrestrial ecosystem (Banff-Bow Valley Study 1996). Managing grizzly bear mortality at a level that prevents population decline is fundamental.

MANAGEMENT IMPLICATIONS

The following recommendations are based on the stated goal of Parks Canada to maintain a naturally regulated population and distribution of grizzly bears in the mountain national parks (Banff National Park 1997). These recommendations are offered as ways to prevent future increases in mortality, to reduce the unnecessary killing of grizzly bears, and to assist in the inter-jurisdictional management of grizzly bear mortality.

During the analysis period, a considerable number of grizzly bear deaths went unrecorded in official park databases, and the records were often incomplete. This has improved in recent years and must continue to improve.

There is some variation in the way mortality data are classified between jurisdictions in the Central Rockies Ecosystem. Park wildlife managers should work with managers from other jurisdictions to develop the same coding conventions and to clearly define the different causes of death.

Acquiring accurate mortality locations is necessary for understanding and managing mortality with respect to access, development, and use of the landscape. Mortality needs to be monitored in the future to understand the effectiveness of management decisions. Additional information needs to be collected such as the distance a bear died from an access route or facility, the type of access route, the condition of the access route at the time of the mortality, the mode of travel of the person(s) responsible for the removal of the bear, presence of food attractants including natural foods, and what, if any, human behaviors played a role in the mortality.

Management of garbage and human and pet food continues to be a problem around Banff, Lake Louise, and in some campgrounds. Effective legislation and enforcement should be employed with respect to food and garbage handling. All backcountry users should be required to store food, garbage, and horse feed in bear-proof metal or seamless PVC containers, or effectively elevate attractants between trees or isolate camp within an effective portable electric fence.

To understand the effects that new management strategies and increases in human use of grizzly bear habitat have on grizzly bear mortality and population status, analyses should be repeated and reassessed in the future with more accurate population estimates.

The use of aversive conditioning programs on roadside- and campground-habituated bears, especially females, should be increased. On-site releases and aversive conditioning of many problem bears would reduce the costs and risks associated with translocating grizzlies.

Efforts should continue to inform the public about bear activity in high human use areas and to educate the public with respect to how to behave in bear country.

All of these recommendations will require adequate funding and administrative support.

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