BIOLOGY, DEMOGRAPHY, ECOLOGY AND MANAGEMENT OF
GRIZZLY BEARS
IN AND AROUND BANFF NATIONAL PARK
AND KANANASKIS COUNTRY

Final Report of the
Eastern Slopes
Grizzly Bear Project
2005

Edited by Stephen Herrero

Eastern Slopes Grizzly Bear Project
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Credits for cover photographs:

Brian Wolitski  Main cover photograph
Anonymous Lake Louise visitor  Grizzly bear family group on footbridge
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Cover design

Rob Storeshaw, Parks Canada, Calgary, Alberta

Document design, layout and formatting:

KH Communications, Canmore, Alberta

Suggested means of citing this document


Suggested means of citing chapters or sections of this document

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Eastern Slopes Grizzly Bear Project,
Environmental Sciences Program, Faculty of Environmental Design, University of Calgary,
Calgary, Alberta, Canada.
DEDICATION

To everyone who cares about grizzly bears and wildlife and the ecological systems and processes that support them.

To the graduate students who were the core researchers: Bryon Benn, Mike Gibeau, John Kansas, Cedar Mueller, Karen Oldershaw, Saundi Stevens, and Jen Theberge.

To the funding supporters who had the vision and faith that our research would be worthwhile.

And to my wife, Linda Wiggins, whose unfailing love and support made my contribution possible.
EASTERN SLOPES GRIZZLY BEAR PROJECT (ESGBP) 
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(with sincere apologies to others who helped but are not listed)

Alan Dibb
Anne Johnston
Anne Weerstra
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Arlin Hackman
Barry Worbets
Bart Robinson
Bill Hay
Bill Poromnuk
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PREFACE

Stephen Herrero

The introduction to this report in Chapter 1 provides details related to the origin and execution of the 11-year-long Eastern Slopes Grizzly Bear Research Project (ESGBP). In this preface I hope to orient readers to the nature of the Final Report. In this Report we present the major research findings of people associated with this diverse and complex project. The fundamental aim of the ESGBP was to contribute science-based understanding regarding the influences that people were having on the grizzly bear population in a 40,000 km² area called the Central Rockies Ecosystem (CRE) of Alberta and British Columbia, Canada. We focused our research on reproduction, mortality, and population dynamics of grizzly bears, and factors that influenced these variables. This progression of topics formed the logical structure for organizing the Final Report. We present the results of our research in the context of grizzly bear conservation, for inevitably individuals who do research on this fascinating species hope that their efforts will contribute to conservation of grizzly bears and their supporting ecosystems.

The ESGBP research was carried out primarily by graduate students at the University of Calgary although many other individuals also contributed substantially to the research. Research results are presented in a variety of formats including complete published papers, summaries of several papers and summaries of research still ongoing. When a given chapter or section has been published this is indicated at the end of the Abstract of the paper. Many publications have been published in peer-reviewed journals or in longer form as theses or dissertations. Some chapters or sections have not been published and appear for the first time in this report. Given the nature of the final report, which summarizes a variety of overlapping research efforts, occasionally using some of the same data but analyzing it in different ways, there is some redundancy in the final report. For example, a given study area figure may appear several times but in a different context. While I tried to minimize such duplication, some was inevitable to allow each contributor to develop their ideas without the reader having to refer to another section of the report.

One factor contributing to the complexity of our research and this report is that our largest study area, the CRE, is made up of smaller, component areas such as the Bow River Watershed, Banff National Park, Kananaskis Country, or the Alberta or BC portions of the CRE. Various research projects focused on different portions of the CRE, or sometimes on the whole area. The reader can use maps we provide to see the basic spatial relationships between these areas.

This Final Report presents the details of scientific research. There has been little attempt to explain basic research approaches or findings in non-specialist terms. This should be done in subsequent documents written for broader audiences. For a snapshot of our principle findings and management recommendations related to them I suggest going to the “summary” and the “management recommendations.”

While we have tried to apply science and rationality wherever possible we have as human beings elected to focus on what we think is important related to grizzly bear conservation. Some of our research involves projection into the future of estimated numbers of people and their behavior, and their effects on grizzly bears. This is an inexact, but essential science, for the ESGBP final report is intended to contribute to a future for grizzly bears, the ecosystems that support them, and people who value and respect them.
SUMMARY: EASTERN SLOPES GRIZZLY BEAR PROJECT FINAL REPORT

Stephen Herrero, Michael Gibeau, Dave Garshelis, Bryon Benn, Jeannette Theberge, Saundi Stevens, Brad Stelfox, Scott Nielsen, Michael Proctor, Scott Jevons, Marc Catter, and Laura Felicetti

DEMOGRAPHY OVERVIEW
Long term survival of independent female grizzly bears (Ursus arctos) was the primary factor influencing whether grizzly bear numbers were increasing or decreasing. The reproductive output of the bears we studied in the Bow River watershed was exceptionally low and not likely to increase in the short run. Since most of the independent female bear mortality was caused by people, managing human-caused mortality to attain high survival rates is essential for population persistence or increase.

THE RAPIDLY DEVELOPING REGIONAL LANDSCAPE
Grizzly bear habitat in Banff National Park (BNP), Kananaskis Country (KC), and surround can be reached after a 1–2 hour drive from Calgary, an affluent city of 900,000 in Alberta, Canada. Calgary’s human population grew by 16%, 1996–2000, the fastest rate of urban growth in Canada. Nearby smaller cities and towns such as Canmore, Cochrane and Bragg Creek also had rapid growth. The oil and gas driven economy will continue to fuel rapid growth and development in Calgary and surround and will encourage more people to be in grizzly bear habitat. Grizzly bear conservation will depend upon managing the cumulative effects of humans. Grizzly bears in this area live in one of the most developed and rapidly developing landscapes where they still survive.

THE ESGBP AND AREAS WHERE WE CONDUCTED RESEARCH
The Eastern Slopes Grizzly Bear Project (ESGBP) began in 1994 in response to regional development pressures and their potential adverse effects on the vulnerable grizzly bear. The primary research area was the Bow River watershed (BRW) from its headwaters in the Rocky Mountains near Bow Lake to approximately where it meets the prairie. This 11,400 km² area included roughly half of BNP and all of the adjacent Alberta Provincial land known as KC plus other Alberta provincial land. A larger research area, approximately 40,000 km², called the Central Rockies Ecosystem (CRE), was also a focus of research in recognition of probable genetic connectivity throughout this area and the large movements of, especially male, grizzly bears. The CRE included Alberta provincial lands as far north as Highway 11, south to and including the Highwood River drainage, and east as far as grizzly bears were found. In British Columbia provincial lands adjacent to the Alberta portion of the CRE and extending to the Columbia Trench were included, as well as Yoho and Kootenay National Parks.

The ESGBP is an independent research group based at the University of Calgary. It has been partly funded and advised by a steering committee made up of representatives from governments (Alberta, BC, and Canada), business and industry, conservation groups and other regional stakeholders. The ESGBP has no formal decision, management or policy role.

THE ESGBP’S 9 YEAR STUDY OF BIOLOGY, DEMOGRAPHY AND ECOLOGY USING RADIOTELEMETRY
During 1994–2002, in cooperation with government agencies, we captured, radiomarked, and monitored 37 female and 34 male grizzly bears in the BRW. Based on this sample we estimated rates of survival and reproduction with a focus on estimating demographic vigor (i.e. the rate of population growth, lambda [λ]) and understanding spatial, temporal and environmental covariates of human-caused mortality. For the radiomarked sample of grizzly bears we also studied morphology, genetic structure (relevant to genetic and demographic fragmentation), nutrition and stress, movements and home range characteristics, resource

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selection, response to human use, habitat effectiveness and security, and denning. In the CRE we also investigated human-caused mortality, regional growth, and the science and policy of grizzly bear management.

**DEMOGRAPHIC RESEARCH RESULTS**

Annual survival rates of radiomarked grizzly bears, 1994–2002, other than dependent young averaged 95% for females and 81–85% for males. Although grizzly bears were mostly unhunted in the BRW, humans caused 75% of female mortality and 86% of male mortality. Females produced their first surviving litter at 6–12 years of age ( \( \bar{x} = 8.4 \) years). Litters averaged 1.84 cubs spaced at 4.4-year intervals. Adult (6+ year-old) females produced 0.24 female cubs per year and were expected to produce an average of 1.7 female cubs in their lifetime, based on rates of reproduction and survival. Summed elasticities for female survival (0.92) far exceeded elasticities for reproduction (0.08) documenting the dominant role of female survival on reproductive output. Although this is the slowest reproducing grizzly bear population yet studied in North America, high rates of survival seem to have enabled positive population growth (\( \lambda = 1.04, \) 95% CI = 0.99–1.09), based on analyses using Leslie matrices. We caution, however, that we are <95% certain that the population is not actually declining. Given the biological nature of grizzly bears and the cost of such research, it is unlikely we will ever know the population status with more certainty. Current management practices, instituted in the late 1980s, focus on alleviating human-caused bear mortality. This emphasis on controlling human-caused mortality is critical to the continued health of this population. If the 1970–80s style of management, with resulting higher human-caused mortality rates, had continued, we estimate that an average of 1 more radiomarked female would have been killed each year, reducing female survival to the point that the population would have declined. Maintaining high survival rates in a landscape as developed as the BRW requires substantial planning and management efforts, public support and adequate budget.

We believe our results regarding grizzly bears radiomarked in the BRW are acceptably precise regarding the probable positive growth rate, 1994–2002. However, our knowledge regarding the status of grizzly bears in the remaining, approximately 30,000 km\(^2\) of the CRE in Alberta and British Columbia, is relatively poor. Over most of this area grizzly bears and ungulates are hunted, with resulting increases in grizzly mortality risk. Extensive resource-related development associated with forestry, mining, and recreation occurs. Demographic research on grizzly bears has not been done. However, within the CRE north of the Bow River (Bear Management Area 4C, Alberta), government research concluded that there was a trend of declining age structure for dead female bears. Females formed a major component of total mortalities. This was identified as being of potentially serious management concern and steps to reduce the mortality rate were seen as necessary (Stenhouse, G., M. Boyce, and J. Boulanger. 2003. Report on Alberta grizzly bear assessment of allocation. Report to Alberta Sustainable Resource Development, Edmonton, Alberta, Canada).

**Postscript to Demographic research results**

Following 9 years of intensive study (1994–2002) of grizzly bears, mortality monitoring was continued for another 2 years. A sample of 18 radiocollared females and 9 males were tracked from the ground during 2003–2004. Two females and 3 males died in 2003 and 4 females and 2 males died in 2004. Four (36%) of these (2 males, 2 females) were natural mortalities, 3 were caused by other bears and 1 by wolves. The 7 human-related loses (4 females, 3 males) were the result of collisions with a vehicle on the highway (n=2), translocations due to nuisance activity (n=3) or being shot (n=2).

Estimated survival for females (all ages pooled) based on these data was 88% (95%CI 72–100%) in 2003 and 71% (CI 45–96%) in 2004. These rates were well below the mean and confidence intervals of the previous 9 years (95% CI 91–99%, yearly range 93–100%). They were also below the minimal rate of survival (91%) necessary to sustain this population (i.e., to achieve \( \lambda = 1 \)), given previous reproductive output. The sample, however, was small and potentially biased.

Results from these last 2 years of monitoring reemphasize two important points discussed in our previous paper: (1) the effects of stochastic events (and possibly increased density-dependent effects) on grizzly bear demographics, and (2) the importance of continued monitoring for a population like this, where
slight changes in bear or human behavior that influence grizzly bear mortality can tilt population trend from positive to negative.

**POPULATION AND HABITAT VIABILITY WORKSHOP**

In 1999 the ESGBP, in conjunction with the IUCN’s Conservation Breeding Specialist Group and 87 participants, conducted a Population and Habitat Viability Assessment (PHVA) using the *Vortex* model. The PHVA report is the only attempt by the ESGBP to project future conditions for grizzly bears at the scale of the entire CRE. Habitat quality and degree of human use and development were incorporated into the model. The model was not assumed to have precise population parameters as input. Best estimates based on available research were used and sensitivity to parameter increase or decrease was documented. Assumptions were explicit so future improvement is possible with additional research.

*Vortex* was programmed to predict the probability of population decline or increase in the future. Risk assessment projections depended most heavily on 2 demographic parameters: the percentage of adult females breeding, and rate of adult female mortality. Percentage of adult females breeding is influenced primarily by nutrition and is not likely to change much in the short term. The rate of adult female mortality depends primarily on people’s actions. This can be influenced strongly by policy and management. PHVA modeling showed that a predicted, significant increase in human population and related development would likely further decrease habitat security. Without changes in management, this was predicted to increase contact between humans and female grizzly bears, increase female grizzly bear mortality rate, and cause a population decline. The PHVA workshop concluded that impacts of humans on grizzly bear habitat and mortality need to be reduced even while numbers of humans in the region increase. To accomplish this, the workshop recommended grizzly bear habitat restoration (primarily by access management) approaching 2% annually in order to decrease probabilities for female grizzly bear mortality. Habitat restoration would proceed until it was scientifically demonstrated that grizzly bear mortality rates were sustainable throughout a given management unit.

**POPULATION DENSITY**

While estimating grizzly bear population density was not a major objective of our research we used radiomarked bears, DNA from hairsnagging, and a capture/recapture design to estimate density in a 4000 km² portion of the BRW. Our estimate was too imprecise to be used for population management but it was convergent with estimates from 2 previous studies. However, neither of these had estimates with acceptable precision. Nonetheless, the 3 studies had convergent results that suggested a population density estimate of 1.2–1.6/100 km² (no acceptable CIs) for the areas studied. In the northwestern portion of the CRE in BC densities were probably higher, 2.2 (95% CI 1.5 – 4.3)/100km² [Apps, C.D., B.N. McLellan, J.G. Woods, and M.F. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management 68: 138–152], reflecting the greater moisture and productivity of this portion of the CRE. The low density estimates for the BRW are consistent with the low reproductive output and further suggest population vulnerability.

**MORTALITY IN THE BOW RIVER WATERSHED**

Based on research previously conducted on other grizzly bear populations we knew, before the ESGBP began, that mortality in the independent female cohort would be the primary factor influencing demographic vigor. Therefore, we researched circumstantial, spatial, temporal and environmental correlates of mortality with the objective of identifying management actions that could lessen female grizzly bear mortality. We analyzed mortality for the radiomarked sample in the BRW. We also analyzed all known mortalities (radiomarked and not radiomarked) that occurred in the BRW 1993–2002. Of 39 known mortalities, 87% (34 of 39) were human-caused. Treaty Indians, who can legally kill grizzly bears anytime outside of national parks, accounted for 20% (8 of 39) of all, known mortalities; government action 18% (7 of 39); citizen action 15% (6 of 39); accidental 15% (6 of 39); natural 10% (4 of 39); research 8% (3 of 39), illegal 5% (2 of 39), misidentification 3% (1 of 39), unknown cause 3% (1 of 39) and legal harvest 3% (1 of 39). These multiple sources of mortality demonstrate the complexity of management response needed. Legal harvest, the single
largest contributor in the Alberta and BC Provincial mortality databases, and the easiest to manage, is a minor factor in the BRW. There is currently no effective dialogue by federal or provincial governments with First Nations, the largest mortality source.

Sex specific data revealed that 41% of all known, human-caused mortalities in the BRW were female bears (n=14). Additionally 3 adult female bears were translocated out of the ecosystem (essentially lost) over the 10 year period. The loss of this many females in the BRW during our study is a potentially serious management concern that was not identified in the analysis of the radiomarked sample. Possibly, the female grizzly bear mortality rate in the BRW may have been higher than we calculated for our radiomarked sample. If this were true our estimate of lambda would have been high.

GRIZZLY BEAR MORTALITY IN BANFF AND YOHO NATIONAL PARKS

For Banff and Yoho National Parks we conducted univariate spatial and temporal analyses to examine the relationship between access, changing grizzly bear management strategies, and grizzly bear mortality, 1971–98. Concurrent with improved management of people’s food and garbage, and management effort aimed at not removing “problem” independent female grizzly bears, the annual number of grizzly bear deaths declined significantly between 1971–84 ($\bar{x} = 7.07$) to 1985–98 ($\bar{x} = 1.43$) 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 with 91% (119 of 131) of known mortalities. Control of problem bears accounted for 71% (85 of 119) of known human-caused mortalities, followed by highway and railway mortalities 19% (23 of 119), unknown cause of death 9% (11 of 119), and research 1% (1 of 119). All 95 human-caused mortalities with known accurate locations were within 500m of roads or 200m of trails whereas only 40% of the study area fell within road or trail buffers. Eighty percent of these mortalities occurred below 2000m and near human settlements and access. Mortalities were concentrated at Banff townsite, Lake Louise, and along the Trans Canada Highway. Management of development, road and trail access, and human food and garbage are critical for managing grizzly bear mortality in these national parks.

GRIZZLY BEAR MORTALITY AND HUMAN ACCESS IN THE CRE

We acquired grizzly bear mortality data from 1972-2002 and 1976-2002 for the Alberta and British Columbia (BC) study areas of the Central Rockies Ecosystem (CRE). We conducted spatial and temporal analyses to examine the relationship between access and changing grizzly bear and land use management practices on grizzly bear mortality. We summarized mortalities by cause of death, sex, age, and cohort. Human-related causes were the primary sources of grizzly bear mortality in both study areas. In Alberta, legally harvested grizzly bears accounted for 48% of 229 known human-caused mortalities, followed by management control (18%), illegal kills (16%), self defense kills (11%), and other causes of death (7%). In BC, 81% of all known mortalities were legally hunted bears followed by management control (16%) and illegal kills (3%). Total human-caused and harvest mortality and percent females in the kill were within management guidelines for population sustainability in both jurisdictions. The total number of grizzly bears and the proportion of females killed both dropped following the implementation of limited entry hunting. Grizzly bears spend much of the year at lower elevations in both study areas, and roads and trails usually follow valley bottoms, potentially fragmenting riparian habitats. Eighty-six percent of 549 mortality locations in Alberta and BC fell below 2000m. Ninety percent of 185 known human-caused mortalities with accurate locations in Alberta and 56% of 369 in BC fell within 500m of roads and 200m of trails. Buffered roads and trails occupied 54% and 41% of the area of suitable habitat (<2400m) in each study area. Area-concentrated kills occurred along many drainages accessible by road or trail and around townsites and First Nations Reserves. Management of access, in particular of open roads, and human food and garbage, and educating hunters are critical issues with respect to managing grizzly bear mortality in the CRE. We present recommendations for reducing grizzly bear mortality.
SPATIAL PATTERNS OF GRIZZLY BEAR MORTALITY IN THE CRE

For the Alberta portion of the CRE (including Banff National Park) we examined the spatial patterns of 297 human-caused grizzly bear mortalities from 1971 to 2002. We explored relationships between mortalities and variables reflecting human development, terrain, and vegetation. Using logistic regression, we modelled the distribution of grizzly bear mortalities based on local landscape attributes as well as examining variation among demographic status, seasons, and mortality type. Grizzly bear mortalities were concentrated in 3 main regions of the Alberta portion of the CRE: (1) Lake Louise; (2) Banff town site; and (3) Alberta Provincial lands near the Red Deer River. Models describing the relative risk of mortality were positively associated with human access, water, and edge features, while negatively associated with terrain ruggedness and greenness indices. Model predictions fit well with a portion of the data withheld for model verification. Overall, relatively little of the landscape was secure from human-caused mortality for grizzly bears. This would be most directly remedied by controlling motorized access. We suggest that risk models be integrated with habitat models for identifying key habitat-related mortality sinks where mortality control should be enhanced, and secure areas where continued maintenance of security should be continued. Management and mitigation of potential habitat-related sinks may be necessary during essential grizzly bear activities such as the hyperphagic berry feeding period (August to October), or during the spring, limited-entry bear hunt, when grizzly bears are at high risk of being killed by humans.

We also did finer scale analysis of spatial and temporal aspects of female grizzly bear mortalities in Alberta and British Columbia, 1972–2002. We analyzed 106 human-caused female mortalities with acceptably accurate locations in Alberta, and 129 in British Columbia. Using a geographical information system (GIS) we analyzed the human-caused, female grizzly bear mortality densities for 2 time periods for each province: 1972–1989 and 1990–2002 for Alberta, and 1978–1989 and 1990–2002 for British Columbia. We present detailed geographic descriptions of areas having identifiable concentrations of human-caused female mortalities for each time period. We suggest that area specific mortality information and its changes over time should be a consideration in management decisions related to human-caused grizzly bear mortality and habitat. Four of the areas that had concentrated human-caused female mortalities over some of their extent were shown in another ESGBP study to also have a high probability of selection by females. These areas were: 1) around the hamlet of Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area and south to and including the Burnt Timber drainage, 3) around Banff townsite and, 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. These areas that are attractive to female grizzly bears also have significant risk of death for them. They are candidates for management action aimed at grizzly bear conservation. Using GIS generated maps we also illustrated the geographic distribution of a number of variables known to be associated with grizzly bear mortality. These variables were: access, the location of grizzly bear and ungulate hunting, the location of protected areas, and land ownership. Understanding the relationship between these variables and human-caused grizzly bear mortality could help to geographically and jurisdictionally focus grizzly bear conservation efforts.

GENETIC AND POPULATION FRAGMENTATION

Population fragmentation has been associated with the extirpation of many grizzly bear populations in the contiguous United States. To explore potential fragmentation of grizzly bears, Proctor gathered genetic samples in southwestern Canada between 1996 and 2001 (Proctor, M.F. 2003. Genetic analysis of movement, dispersal and population fragmentation of grizzly bears in southwestern Canada. Dissertation, University of Calgary, Alberta, Canada). The ESGBP collected similar samples within the BRW. Using genetic tools Proctor explored bear movement across Highway 1 and between the BRW and adjacent geographic areas. The movement trends he found in the eastern slopes area across Highway 1 were consistent with those found in his regional study area. He found little evidence for female movement across human transportation and settlement corridors that had significant amounts of human use. He also found consistent evidence of male movement. The amount of genetic differentiation found across Highway 1 was low relative to other areas within his larger study area. He found evidence of male and female movement and/or dispersal across the continental divide to the south across Elk Pass between Alberta and British Columbia. He found less evidence of movement across the continental divide north of Highway 1 into British Columbia. These
results indicate that genetic connectivity across Highway 1 is being mediated by male movement while demographic connectivity is fractured (i.e. females’ movement is limited). Considering the peninsular shape of the remaining distribution of grizzly bears in southwestern Canada, Proctor recommends that the long-term population fragmentation potential from the major east-west highways (1, 3, 11, and 16) should be considered for management attention.

**BODY CONDITION INDEX, REPRODUCTIVE HORMONE LEVELS AND REPRODUCTION**

Seeking potential explanations for low cub production by ESGBP bears trapped in the BRW, a comparison of select health parameters was made between ESGBP and Foothills Model Forest Grizzly Bear Project (FMF) bears (grizzly bears living further north but still on the eastern slopes). The parameters considered were body condition as a reflection of nutrition (indicated by a Body Condition Index [BCI]) and reproductive hormone levels as a reflection of reproductive function. The working hypothesis was that reduced reproductive output in ESGBP grizzly bears was a result of low energy intake causing diminished reproductive function. Results were preliminary due to small samples.

ESGBP bears tended to be in poorer body condition (lower BCIs) than FMF bears captured at the same time of year, a difference that was most notable among adult males. In both sexes, luteinizing hormone (LH) concentrations were significantly lower in ESGBP bears than in FMF bears. Results from a comparison of body condition and reproductive hormone concentrations between Eastern Slopes and FMF bears cannot be used to disprove the hypothesis that reduced reproductive output (late age of first successful reproduction, long interval between litters, and low reproductive rate) in ESGBP bears is a result of low energy uptake intake (especially in males) causing diminished reproductive function.

**DIET AS INDICATED BY STABLE ISOTOPE ANALYSIS**

Isotopic analysis of ESGBP grizzly bear hair was conducted to further comment on the hypothesis that low reproductive output might be due to low energy intake. Analysis of stable isotopes of carbon and nitrogen present in hair indicate the dietary contribution of plant versus animal tissue. Since hair is replaced each year in bears the values reflect the diet consumed during growth of the hair. While the isotope values suggested that males ate more meat than females, this grizzly bear population probably depended on plant matter for the bulk of its nourishment. The low reproductive output of the population probably reflects this relatively low-energy diet. The small number of grizzly bears sampled suggests caution with the results.

**HOME RANGES**

We documented use of space by ESGBP bears trapped in the BRW and compared this to spatial use by bears trapped and monitored in the Upper Columbia River basin (west slope) portion of the CRE (data provided by John Woods, Research Biologist, Glacier and Mt. Revelstoke National Parks, Revelstoke, BC). Eastern slope bears had large mean home ranges (95% Fixed Kernel), males 1405 km², and females 520 km². Western slope bears had much smaller mean home ranges (100% Minimum Convex Polygon), males 507 km², and females 103 km². These differences in home range size most likely primarily reflect the lesser productivity of the eastern versus western slopes. They may also reflect different methods for home range calculation. They also show that because of their larger home ranges, grizzly bears living in the eastern slopes have greater exposure to interaction with humans. Consistent with results of DNA studies a larger percentage of male versus female grizzly bears crossed the Trans Canada Highway. For nearby Highway 40, a lower volume, paved highway in the Kananaskis, both males and females frequently crossed.

**LANDSCAPE SELECTION BY ADULT FEMALE GRIZZLY BEARS**

Two ESGBP projects developed resource selection functions to model use versus availability of landscape units by wary, adult female grizzly bears. Research was conducted at different scales and used somewhat different approaches to understanding landscape selection by bears.
Stevens analyzed second order selection for landscapes and associated variables within and between female home ranges. She found that density of high greenness, and distance to high greenness, were the most important predictors of female grizzly bear occurrence at this relatively coarse scale. Stevens also used GIS mapping to overlay areas of high landscape selection probability with areas where habitat was classified as secure. These results are summarized under the topic of “security area analysis” in this summary.

Theberge analyzed finer-scale, third-order selection for landscapes and associated variables. She concluded that locations of female grizzly bears were correlated with environmental conditions and heterogeneous landscape patterns at different scales. Landscape selection appeared to be taking place simultaneously, at multiple scales. Selected areas had the following characteristics: within 60 metres of vegetation edges, high levels of vegetation diversity within 300-m and 1.5-km windows, rugged terrain within broad 3.0-km areas, graminoid meadows, avalanche paths, or riparian areas.

In applying Theberge’s seasonal resource selection functions to the eastern slopes of Alberta landscape, we identified 4 geographic areas containing a concentration of high probabilities of adult female occurrence. These areas are described in this summary under the topic of “Spatial patterns of grizzly bear mortality in the CRE,” paragraph 2). We also identified numerous smaller pockets where there was a high probability of female grizzly occurrence. These areas were distributed throughout the study area but especially south of the Trans Canada Highway. We comment on the management implications of these concentration areas.

HABITAT USE AND THE INFLUENCE OF HUMANS AND DEVELOPMENT

There was an influence on grizzly bears radiomarked in the BRW from proximity to people and development beyond directly increasing mortality probabilities. Both wary and habituated adult female grizzly bears were affected by human presence. In the relative absence of humans, these bears made more efficient use of higher quality habitats by moving shorter distances while foraging. Increased human presence eroded this habitat optimization. In the extreme, habituated female bears traveled further in utilizing sub-optimal habitats. This would likely decrease the net energy available for growth and reproduction.

Of 4 types of developments studied, the Trans Canada Highway (TCH) was avoided most by grizzly bears. Female bears avoided the busy freeway regardless of the habitat quality or time of day. Males, and especially subadult males, were found closer to the TCH when within or adjacent to high quality habitat and during the human inactive period. These observed responses, in areas without fencing and associated crossing structures, may not be solely due to the TCH, but to the higher overall density of humans associated with the valley that includes the highway. Grizzly bears crossed roads in areas where habitat quality was high. However, when grizzly bears crossed high-volume roads they moved into areas of higher quality habitat. This pattern did not occur on low-volume roads, suggesting that there is a trade off between the risks of crossing roads and benefits in terms of access to higher quality habitat.

Unlike paved roads that were located in valley bottoms and good quality habitats, high use trails were widely distributed throughout all types of habitats within the study area. When human activity was low, we found bears were closer to trails when in high quality habitat and further from trails when distant from high quality habitat.

We conclude that the cumulative effects of human use and developments such as railways, highways, and trails within the Bow Valley can limit access to important habitats, thereby negatively impacting grizzly bears.

SECURITY AREA ANALYSIS

In the past, habitat effectiveness modeling was the primary tool used to predict the impact of human activities on bears and their habitat. The model fell short, however, in not estimating the human encounter rate and associated mortality risk. For each jurisdiction in the CRE we calculated the percentage of the productive landscape that had undisturbed and connected minimum size units of 9.0 km², the mean size of an adult female's daily foraging area. The percent of productive land base where adult female grizzly bears have
a low probability of encounters with people (secure) depends on the amount of productive land available to a bear and the extent of human influence on that land. British Columbia provincial lands had the largest percentage of secure habitat (50%), followed by Alberta provincial lands and national parks with 43% secure habitat in both, and Kananaskis Country with 36%. None of these areas met the current target level of 68% considered to be adequate security set by the USDA Forest Service in the Northern Continental Divide grizzly bear ecosystem in northwest Montana. Results suggest management intervention regarding secure habitat will be necessary to attain acceptable mortality rates for independent female bears. Results also underline the importance of a cooperative, coordinated inter-jurisdictional management approach.

Habitat quality can also be included in evaluation of grizzly bear security areas. High quality habitat is in short supply in mountainous environments, and only a small proportion of each jurisdiction encompasses secure high quality habitat. British Columbia provincial lands have the largest percentage (13%) of their available land base in secure high quality habitat. In national parks there is the least amount of available land base in secure high quality habitat (5%). In Banff National Park, an average of 4% of Bear Management Units are secure high quality habitat, 6% in Yoho, 7% in Kananaskis Country and 12% in Kootenay National Park. It is important to identify areas of high quality secure habitat. Based on this managers can work to prevent further loss of what we have shown is selected and probably important grizzly bear habitat.

Security at the level of an adult female grizzly bears’ home range determined by radio telemetry revealed that for 30 female grizzly bears in the Eastern Slopes, an average of 39% of the home range was secure, with only 7% secure high habitat quality. For 10 adult female grizzly bears in the Western Slopes, an average of 62% of the home range was secure and 22% secure high quality habitat. Secure high quality habitat for the Eastern Slopes bears ranged between 0 and 34% of the home range. Secure high quality habitat for the Western slopes bears ranged between 7 and 47% of the home range. The results raise the question whether this level of security is sufficient for a long term viable grizzly bear population. This is particularly important since the Bow River watershed grizzly bear population’s positive growth rate, 1994–2002, was possible because of 95-96% survival from year to year by adult females.

CUMULATIVE EFFECTS OF DEVELOPMENT IN ALBERTA’S EASTERN SLOPES

In Alberta a progression of landuses during the 20th century were responsible for significant economic growth and human population expansion, but also lead to the loss of grizzly bear habitat and numbers throughout much of the province. These landuses have included cropland agriculture, livestock grazing, and urban, suburban, and acreage expansions. Other landuses, most notably forestry, the hydrocarbon industry, and the recreational sector, have left their anthropogenic footprint extensively across historic and current grizzly habitat. Their influences on grizzly bears have been expressed in terms of grizzly bear mortality and compromised habitat. Collectively, these landuses require a large network of linear features (major roads, minor roads, hiking/biking trails, transmission lines, seismic, pipelines, etc.), now in excess of 1 million km in Alberta.

Grizzly bear/human encounters in the CRE will very likely intensify given the access infrastructure and the almost certain expansion of mountain and foothill commuting towns such as Canmore, Cochrane and Bragg Creek, and the mobility and increase of a Calgary population approaching 1 million. Whereas Calgary has grown by an average annual rate of 4% in area and 2.5% in population, during the past several decades, the growth of some of its satellite communities and acreage complexes has been even higher. If these growth rates persist in the coming decades, the City of Calgary will contain ~1.5 million people by 2030 and the central eastern slopes commuting towns will be home to greater than 100,000 foothill and mountain residents. As this young, prosperous human population satisfies its increasing appetite for front-country and back-country recreational pursuits, the attendant bear mortality may overwhelm the conservative reproductive rates exhibited by grizzly bear females in this region. The current number of 3.1 million visitors and 7.7 million visitor days for Banff National Park is projected to grow to 10 million annual visitors by 2030, and growth is likely to be accompanied by increased levels of both front-country and back-country recreational activities. Unless managed effectively, the combined mortality rate in the region will threaten the future of grizzly bears.
As the area, length and intensity of linear features in Alberta continues to grow, it is becoming increasingly clear that access management has been neglected across large tracts of remaining grizzly bear habitat. Maintaining the current range and populations of grizzly bears in the CRE will demand bold thinking by contemporary landscape managers, for their decisions today will largely define the future of grizzly bears in the next several decades. Ultimately, resource managers must help society recognize that there are clear trade-offs between the level and intensity of our landuse footprint and the viability of grizzly bear populations. Recognition of these trade-offs can lead to productive discussions about acceptable thresholds for such landscape variables as road density and use, back-country visitation, and habitat area and connectivity. Clear recognition of trade-offs between social, economic, and ecological indicators, such as grizzly bear populations, is key to exploring best practice options.

DENNING

The ESGBP observed the nature and distribution of grizzly bear dens since the initiation of the project in 1994. Following a sample of approximately 25 radio-collared bears to their dens each year complemented earlier research and eliminated possible bias for dens visible from the air. Field researchers surveyed den sites of radio-collared bears opportunistically while in the field for other research purposes. Therefore, of 173 den locations obtained by aerial telemetry (1994-2001), only 30 of those sites were characterized from the ground.

Over the course of ESGBP research, we documented grizzly bears entering their dens between mid-October through to the end of November. In the spring, the earliest emergence documented was mid-March and the latest was mid-May. Radio-collared females with cubs in our study had a mean emergence date of May 12 compared to April 16 for adult males.

All dens we surveyed were found in the upper sub-alpine at elevations between 2012m (6700ft) and 2432m (8100ft) with a mean elevation of 2253m (7500ft). All of our grizzly bear dens surveyed were located at altitudes where preliminary data suggests that thermal inversion is a prevalent phenomenon.

Grizzly bears were specific about the slope angle where dens were dug. The mean slope angle for dens we investigated was 33 degrees (range 26–39 degrees).

SUMMARY OF ESGBP MANAGEMENT RECOMMENDATIONS

(See chapter 15, pps. 228—242 for detailed version. Priority 1 (P1) implement within 2 years, Priority 2 (P2) implement within 5 years):

1. DEMOGRAPHY AND MONITORING

   Goal: To achieve a sustainable human-caused grizzly bear mortality rate throughout the Central Rockies Ecosystem (CRE) that is scientifically documented by collecting adequate data, with an established level of acceptable risk, which supports a high probability for the long-term survival of grizzly bears in the CRE.

   1a. Establish science-based survival (mortality) rate targets for adult female bears that would have a high probability of supporting population growth or maintenance (lambda ≥1) for each grizzly bear population management unit in the CRE. P1

   1b. Monitor survival/mortality rate and reproduction in the Bow River Watershed. P1

   1c. Develop and apply non-invasive DNA “capture-recapture” designs to calculate and monitor relative abundance, derive population estimates against which to evaluate human-caused mortality, and as one means of documenting distribution changes. P1

   1d. Use annual counts of females with cubs as a coarse index of population trend. P2

   1e. Have periodic scientific peer review and inform the public regarding the scientific basis for grizzly bear population estimates. P1
1f. Given the extremely low reproductive output of grizzly bears studied in the Bow River watershed, use research to better understand the reasons. P2

1g. Continue research regarding body condition and reproductive hormones. P2

2. MORTALITY: RECORDING, UNDERSTANDING AND MANAGING
Goal: To document, evaluate, understand and sustainably manage grizzly bear mortality.

2a. Document, analyze and report annually on grizzly bear mortality in the Central Rockies Ecosystem. P1
2b. Develop programs to be able to manage each significant source of grizzly bear mortality in a responsive way with annual reports and annual review of mortality management programs and their success related to cause-specific mortality. P1
2c. Use understanding of spatial aspects of grizzly bear mortality in the CRE for input into planning human activities that have a significant grizzly bear mortality probability so as not to exceed the established human-caused, mortality rate limit for each management unit. P2

3. HABITAT: DISTRIBUTION, SELECTION, SECURITY, CONNECTIVITY
Goal: To define and implement habitat standards that would support grizzly bear persistence.

3a. Using the best available data on landscape selection, by especially female grizzly bears, work toward CRE-wide identification and protection of grizzly bear habitat. P2
3b. Using the best available science establish habitat security targets that would support human-caused mortality rate goals. P2
3c. Maintain, restore or mimic ecological processes in order to recreate plant and animal communities that are more similar to those grizzly bears experienced in the CRE when First Nation peoples were the only humans. P2
3d. Apply both coarse and fine scale selection models to landscape management to ensure that habitat important to female grizzly bears is conserved. Also, support the Integrated Decision Tree Approach for habitat mapping. P2
3e. Begin to systematically restore grizzly bear habitat in the CRE. P2
3f. Establish and apply targets for grizzly bear distribution, habitat connectivity and fragmentation. P2

4. BEAR-HUMAN CONFLICT: AVOIDING AND MANAGING
Goal: To work toward minimizing human-grizzly bear conflict and to provide for safety for grizzly bears and humans.

4a. Develop and enforce regulations related to human food and garbage attractants throughout the CRE. Encourage public involvement using the bear smart community model and other community involvement approaches. P2
4b. Maintain and evaluate aversive conditioning programs, especially for female grizzly bears. Consider alternatives that may be more cost effective. P1
4c. Develop integrated CRE-wide monitoring of grizzly bear-human conflict to serve as a basis for corrective management actions. Report results yearly. Analyze every 5 years. P1
4d. Inform the public regarding grizzly bear activity in high human use areas. Continue with periodic use restrictions related to human safety or grizzly bear needs. Continue to experiment with removing natural attractants such as wild berries from high human use areas. P1
4e. Continue to monitor human land use and to document its relationship with grizzly bear landscape use and mortality probability. P2

5. INTERAGENCY COORDINATION AND COOPERATION
Goal: To support agencies working together toward coordinated, integrated data collection related to grizzly bear research and management. At the same time to recognize agency jurisdictional autonomy.

5a. Work toward coordinated, integrated data collection and grizzly bear management, yet retain jurisdictional autonomy. P1
5b. The CRE should remain one geographic area for interagency coordination related to grizzly bear management. P1

6. PLANNING, MANAGEMENT, STRATEGIES AND PROCESSES
Goal: To continue to develop research, planning and management structures and products that will support and guide actions to achieve a non-declining grizzly bear population in the CRE.

6a. Continue to develop and detail agency specific and CRE-wide conservation strategies for grizzly bears. P2
6b. Encourage peer-reviewed publication of research regarding grizzly bear management and its scientific basis. Consider periodic program review by highly qualified scientists regarding the scientific basis for management. Provide opportunities for public comment and information exchange. P2
6c. Design access and facility management and planning to support grizzly bear persistence. P2
6d. Target research to address threats that have critical knowledge gaps. P1

7. PUBLIC, BUSINESS AND FIRST NATION INVOLVEMENT AND INFORMATION EXCHANGE
Goal: To continue to refine processes for informing and involving various societal sectors in grizzly bear management.

7a. Refine and expand societal understanding and involvement in grizzly bear management. P2
7b. Establish a mechanism to maintain some of the public involvement and information that were part of the Eastern Slopes Grizzly Bear Project. P2
7c. Develop further communication with First Nations regarding grizzly bear ecology and management. P1
8. FUNDING TO MAINTAIN GRIZZLY BEARS
Goal: To adequately fund research that will inform and support maintaining a non-declining grizzly bear population in the CRE.

8a. Adequately fund research, management and planning directed toward long-term maintenance of grizzly bear populations. Use multi-stakeholder funding approaches developed by the ESGBP to do this. P1

9. IMPLEMENTATION OF ESGBP MANAGEMENT RECOMMENDATIONS
Goal: To achieve the goals and implement the management recommendations of the ESGBP.

9a. Form an ESGBP implementation committee. P1
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CHAPTER 1

THE EASTERN SLOPES GRIZZLY BEAR PROJECT AND SCIENCE-BASED GRIZZLY BEAR CONSERVATION
1. THE EASTERN SLOPES GRIZZLY BEAR PROJECT AND SCIENCE-BASED GRIZZLY BEAR CONSERVATION

Stephen Herrero

Maintaining grizzly bear (Ursus arctos) populations and the habitat needed to support them is one of the best known, most researched and yet most challenging conservation issues in Canada and the United States. In the contiguous western United States extensive grizzly bear habitat that remained by about 1850 subsequently became very fragmented by human settlement. By 1920 most of the remaining grizzly bear populations were in the hundreds or fewer and isolated from one another. Human-caused mortality then resulted in extirpation of all but the largest, more northern, populations in the United States (Storer and Tevis 1955, Brown 1985, Mattson and Merrill 2002). Of 37 grizzly bear populations that survived in 1922, only 6 were left by 1975 (Servheen 1999). Grizzlies lost a significant portion of their range in North America (Figure 1) and most of their range in the contiguous United States (Figure 2). This and low population numbers in the contiguous United States led to the species being classified in 1975 as threatened under the Endangered Species Act of 1973.

Figure 1. Current (darker) and historic (ca. 1800) distribution of grizzly bears in North America. Adapted from Servheen (1990) by Ross 2002.

Figure 2. Estimated distribution of grizzly bears in the contiguous lower 48 United States in 1922 (left) and 1999 (right). From Merriam (1922) and Servheen (1990, 1999a) by Ross 2002.

In Canada grizzly bears have maintained more of their range and population but have been extirpated from prairie and some foothill and boreal environments and productive, large valleys in southern British Columbia (Figure 3) (McLellan 1998). Much of the grizzly bear range in southern Canada, including that of the grizzly bears in our study, is now peninsular or island in shape (Figure 4) (McLellan 1998).
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Peninsular shaped ranges of grizzly bears have extensive fringe and hence contact with humans thus increasing mortality probability. Island populations are isolated from one another, are often small, and subject to extirpation. Remaining habitat along the southern fringe of grizzly bear distribution in Canada is becoming increasingly fragmented by a combination of highways, human settlement and human-caused grizzly bear mortalities (Proctor et al. 2002, Proctor 2003, Proctor and Paetkau 2004). Extant Canadian grizzly bear populations in Canada are classified by the Committee on the Status of Endangered Wildlife (COSEWIC) as being of “special concern” (Ross 2002). The most endangered are 8 isolated grizzly bear populations in southern British Columbia (Ross 2002). In each case the cause of population isolation and endangerment has been human development that did not take into account grizzly bear populations.

The biological nature of grizzly bears, their so-called life history traits, interacting with people’s propensity to occupy or use grizzly bear habitat and to kill grizzly bears, are the root cause of the challenge of maintaining populations. The species evolved to have relatively slow rates of population growth set by late age of first reproduction, small litter sizes, and long interbirth intervals. These biological characteristics are amplified in interior mountain populations. Here grizzly bears are smaller than are coastal bears of the same species. Interior grizzly bears typically live in areas of low natural food production compared to coastal areas (Ferguson and McLoughlin 2000). They also experience high year to year variability in the production of key fattening foods such as berries (Hamer and Herrero 1983: p. 108) or whitebark pine nuts (Mattson et al. 1994). This variability apparently selects for later age of maturity, longer interbirth interval, and potentially greater longevity (Ferguson and McLoughlin 2000). These traits have evolved to match reproduction to past environmental characteristics. High levels of human-caused mortality are something grizzly bear reproduction is not adapted to.

Low biological resilience is a major life history trait that makes grizzly bear conservation challenging in the face of population and habitat fragmentation and accompanying higher rates of human-caused mortality. Resilience is the ability of a system to absorb disturbance and still maintain basic structure and function (Holling 1973). Weaver et al. (1996) applied this concept to three hierarchical levels of organization of grizzly bears. Individual grizzly bears have some flexibility of diet but because grizzlies are part of the mammalian order Carnivora they have fast acting, non-specialized digestive systems, and they need to eat foods such as young green vegetation, berries, or meat that are quick to digest (Mealey 1980, Hamer and Herrero 1983). When readily digestible foods are not available energetic stress follows. At the population level there is little or no conclusive evidence of a significant reproductive increase or increased survivorship by young grizzlies to compensate for increased mortality (McLellan 1994). Because of this grizzly bear populations recover slowly from human-caused decline and then only if causal circumstances are alleviated. High adult female survival, greater than 92% each year, has been found for all Rocky Mountain populations estimated to be stable or increasing (McLellan 1989, Wielgus and Bunnell 1994, Eberhardt et al. 1994, Weaver et al. 1996). The third hierarchical level where grizzly bears show low resilience is at the metapopulation level. In nature, isolated animal populations may be linked by dispersal thus increasing their ability to recover after population decline. However, grizzly bear females show strong fidelity for their home ranges and young females typically disperse slowly over a period of years and usually less than the diameter of their mother’s home range (McLellan and Hovey 2001). Dispersing young females must be able to live and survive in an area in order to disperse through it. Female grizzly bears south and north of the Highways 3 and 3a in southern Alberta and British Columbia appear to be almost completely isolated from one another because young females cannot survive over multiple years during dispersal (McLellan and Hovey 2001, Proctor et al. 2002).

Along the current southern and eastern edges of grizzly bear distribution in North America, including southern Alberta and British Columbia, human-caused mortality and habitat competition limit grizzly bear populations (McLellan 1998). Here most adult grizzly bear mortality is human-caused. This is true even in places where there is no grizzly bear hunting (Mattson et al. 1996, Benn 1998, McLellan et al. 1999, Benn and Herrero 2002). The probability of human-caused adult grizzly bear mortality is related to the rate of contact with people and the potential lethality of each encounter (Mattson et al. 1996). Along the edges of grizzly bear distribution there often is extensive contact with human beings and our developments.

“Theoretically grizzlies could coexist with large numbers of humans if the humans were unarmed, tolerant of
(occasional) injury and competition for resources, and aggregated in the poorest grizzly bear habitat” (Mattson et al. 1996). If this were the case then grizzly bears would not need areas secure from people to survive. Despite low reproductive rates, if mortality does not exceed reproduction, grizzly bear populations will grow to the carrying capacity of the environment. The challenge is maintaining high survival rates for adult females and keeping populations linked into units large enough to persist over time and despite natural and un-natural habitat disturbance. Recent successful recovery and expansion of the Greater Yellowstone Ecosystem grizzly bear population is testimony to what is possible regarding population recovery (Pyare et al. 2004, Schwartz et al. In press).

BRIEF HISTORY OF GRIZZLY BEARS IN AND NEARBY BANFF NATIONAL PARK AND KANANASKIS COUNTRY

Grizzly bears and First Nation peoples have been part of the present day Banff National Park - Kananaskis Country landscape for thousands of years. A historical study of grizzly bears and people in and nearby Banff National Park concluded that indigenous people had little effect on grizzly bear numbers although they did hunt them (Noble 1972: p.19). Introduction of repeating rifles and establishment of markets for grizzly bear hides, meat and trophies changed this. The Hudson’s Bay Company briefly operated a trading post, Bow Fort (Peagan Post), on the north side of the Bow River between Morley and Exshaw. Between August 10, 1832 and January 9, 1833 the HBC account book had entries for 23 large grizzly hides and 10 cub hides (Noble 1972: p. 17, McCrory and Herrero 1982). A few hundred kilometers southeast and in the Cypress Hills, a wooded “island” in the Alberta - Saskatchewan prairie, Hudson Bay Company trader Issac Cowie in 1871 reported a “half-kill” of grizzlies. This numbered 750 hides (Stegner 1962: p. 70).

The establishment of “whiskey posts” at present day High River in 1865 and Calgary in 1870 further expanded markets for grizzly bear and other pelts. Major agricultural settlement of grasslands just east of present day Kananaskis Country and throughout the prairie in the 1880’s was coupled with extirpation of bison and grizzly bears from this biome. Widespread killing of grizzlies, especially by ranchers, continued into the foothills, including eastern portions of present day Kananaskis Country, as cattle ranching expanded (McCrory and Herrero 1982). There was little effective regulation of grizzly bear killing through the 1960s (Nagy and Gunson 1990: p.6, Herrero 1994). By 1970 the Alberta Wildlife Division realized that grizzly bears were declining in the area that was to become Kananaskis Country and that this was caused by excessive human-caused mortality. Grizzly bear hunting was closed in Kananaskis Country in 1970 and has remained so, except for 1987, because of concern for the population.

Limited but ground-breaking biological research on the grizzly bear population in Kananaskis Country took place in the late 1970s and early 1980s. This research was sufficient to establish that grizzly bears in eastern, foothill portions of Kananaskis Country survived only in low densities but westward into the mountains densities were higher. Overall productivity and density of the population was low (Carr 1989, Wielgus 1986, Wielgus and Bunnell 1994).

Present day Kananaskis Country has evolved into a multiple use landscape with road development, tourist facilities, extensive recreational use including ungulate hunting, logging, grazing and oil and gas exploration and development. While many hiking trails were planned to minimize incursion into productive grizzly bear habitat and to help people avoid unwanted encounters with grizzly bears (Herrero et al. 1986), the landscape is becoming more human dominated and the opportunity for grizzly bears to live without contacting people is constrained (Benn 1998, Gibeau 2000, Gibeau et al. 2001).

Banff National Park lies to the north and west of Kananaskis Country and is contiguous with it. Portions of it have been protected since 1885 when Banff Hot Springs Reserve was established. By 1930 the protected area had grown to include most of present day Banff Park and Kananaskis Country. In 1930, with application of the Transfer of Resources Act, the present boundaries were mostly established and today’s Kananaskis Country became the Kananaskis Provincial game reserve (McCrory and Herrero 1982, Herrero 1994). The coming of the Canadian Pacific Railway line in 1883 opened today’s Banff National Park area to more use. Already, by 1887, grizzly bear numbers were probably reduced to “below optimum population levels,” particularly in areas such as the accessible Bow River Valley (Noble 1972: p. 26). While most animals were protected in the park, a 1909 regulation gave the newly formed Warden Service the right “to destroy, when necessary, ‘noxious, dangerous, and destructive animals’ which included the grizzly” (Noble 1972: p. 34).
Despite occasional control killing of grizzly bears, in 1939, well-known biologist C.H.D. Clarke, based on an extensive biological survey he conducted, suggested that the population exceeded 100 (Clarke 1939). While little faith should be placed in the specific numerical estimate, grizzly bears were surviving with Park and Warden Service protection.

While the CPR delivered well off tourists to the Park, the Park opened to the general public in 1915 when automobiles were first allowed. One of the first reported major conflicts between tourism development and grizzly bears occurred in 1936 when 4 grizzly bears were shot at work camp dumps during construction of the Banff-Jasper Highway (Noble 1972: p. 56). By 1969 tourism garbage and its handling were having a significant effect on grizzly bears. Park Naturalist Buck Cunningham reported seeing 23 grizzlies at the Lake Louise Dump during a 6 hour period in fall of 1969 (Noble 1972: p. 88).

Human-caused grizzly bear mortalities within the park were high during the 1960s and 1970s related primarily to removal of problem bears that were used to feeding on people’s food and garbage (Benn 1998, Benn and Herrero 2002). The problems caused in Banff Park by grizzly bears becoming used to feeding on people’s food and garbage culminated in 1980 when a large male grizzly bear, attracted by garbage at the Caboose restaurant in Banff, fatally injured one person and seriously injured 3 others over a 2 week period (Herrero 1985: p. 65-68, Herrero and Higgins 2003). These tragic events forced Parks Canada to encourage commercial development of bear-proof garbage storage facilities. Grizzly bear mortalities and human injuries associated with poorly stored food and garbage began to decrease by 1984 (Benn 1998, Benn and Herrero 2002, Herrero and Higgins 2003). Many of today’s conflicts between grizzly bears and people in Banff Park and Kananaskis Country still involve people’s food and garbage serving as attractants. However, the Canadian national parks have become world leaders in bear-proof food and garbage storage. Parallel development of world class, bear-proof, food and garbage storage has also occurred in Kananaskis Country (Herrero et al. 1986).

Today’s challenges for grizzly bear survival center around Banff National Park being one of the most developed areas in the world where grizzly bears survive (Gibeau 2000, Herrero et al. 2000) and the over 4 million visitors the park receives each year. High human use also occurs in Kananaskis Country. In surrounding Alberta and BC crown lands people’s food and garbage are not as well managed and continue to attract grizzly bears and result in removals or mortalities (Benn 1998, Benn and Herrero 2002). Grizzly bear hunting also occurs in the region on most Alberta and British Columbia crown lands that are not protected areas. Despite a plethora of potential mortality sources for grizzly bears, the bottom line is maintaining human-caused mortality at a level where the grizzly bear population is not declining and having scientifically sound data to know this with an acceptable level of certainty.

THE EASTERN SLOPES GRIZZLY BEAR PROJECT

The Eastern Slopes Grizzly Bear Project (ESGBP) began in 1994 in response to regional development pressures and their potential adverse effects on the vulnerable grizzly bear. The project and its membership evolved from several societal changes (Herrero et al. 1998). In 1988 the government of Canada amended the National Parks Act. Changes included recognition that ecological integrity was the primary objective of national park management. Because grizzly bears are difficult to maintain in landscapes with extensive human use the species’ status became an indicator of ecological integrity for Parks Canada. It was also known that grizzly bears were a landscape species and that some individuals moved freely between national park areas and surrounding lands (Russell et al. 1979, Raine and Riddell 1991). As in the United States grizzly bear conservation in national parks was recognized as requiring integrated management with surrounding jurisdictions (Dueck 1990, Herrero 1995).

In 1992 the federal government enacted the Canadian Environmental Assessment Act (CEAA). This broadened the scope of traditional environmental assessment to include the cumulative effects of development at a landscape scale. The following year (1993) the Alberta Environmental Protection and Enhancement Act was passed. This also included a provision for assessing the cumulative impacts of development. Potential landscape scale, cumulative, adverse effects of proposed development on grizzly bears in Alberta became important in evaluating the Westcastle Resort complex (NRCB 1993a) and AMOCO’s proposal to drill an exploratory well in the Whaleback (ERCB 1994). Decisions regarding
potential adverse, cumulative effects of these developments on grizzly bears were not able to be informed by empirical data regarding grizzly bears since studies were lacking.

There was also a lack of scientific understanding regarding the status of grizzly bears in Banff National Park, Kananaskis Country and surround. In the early 1990s a major housing and recreational development was proposed on a large tract of privately owned land adjacent to the mountain community of Canmore and a few kilometers from the eastern border of Banff National Park. The recently formed Alberta Natural Resources Conservation Board (NRCB) had a mandate to review large scale recreational developments that could affect natural resources on crown (public) lands. Public hearings were held and submissions received. The scope of the proposed development and its potential adverse effects on grizzly bears became issues around which approval hinged. The Board decided to reject a major portion of the proposed development in the Wind Valley over concerns regarding grizzly bears (NRCB 1993a). This decision was again made with concern for adverse effects on grizzly bears but without empirical data on their status.

The need to be able to predict the cumulative effects of development on grizzly bears was further underlined in 1990 when the Province of Alberta completed its review of the status of grizzly bears (Nagy and Gunson 1990). This documented not only historic declines in numbers, but also unsustainable legal hunting mortality, especially during 1980-1988. Alberta responded by launching a more sensitive, limited entry system for managing grizzly bear hunting.

In 1994 the ESGBP evolved from the foregoing background. Diverse societal elements and individuals were concerned for a variety of reasons about the status of the grizzly bear population and the cumulative effects of development in Alberta and adjacent portions of British Columbia. Documenting and understanding variables influencing grizzly bear population demography and the effects of various human activities on grizzly bears became primary research objectives. The goal was to contribute toward a scientific understanding of grizzly bear biology, ecology and demography in the CRE. This research was intended to inform management, planning and policy decisions that affect grizzly bears. Neither the Project, nor its members, was formally designated by any group or agency. The ESGBP evolved as an association of jurisdiction and deposition holders, and other land users in the grizzly bear’s range in the Central Rockies Ecosystem. The principal participants were Parks Canada, the Province of Alberta (Energy and Utilities Board, Fish and Wildlife, Parks, and Kananaskis Country), the Province of British Columbia (Fish and Wildlife), the University of Calgary, conservation, community and recreation groups, the oil and gas industry, the forest products industry, the land development industry, and the cattle industry. The research was carried out primarily by graduate students and was guided by a steering committee composed of primary project supporters, and university supervisory committees (Herrero et al. 1998). The Steering Committee was also responsible for helping to raise funds to support research and some public outreach regarding grizzly bears. Outreach was accomplished primarily by establishing and maintaining a website www.canadianrockies.net/Grizzly and by preparing documents, commercial videos and public events.

GRIZZLY BEARS AND OUR SOCIETY

During February of 2004 anyone driving west on the Trans Canada Highway toward Kananaskis Country and Banff National Park was guaranteed to see 2 grizzly bears. Each appeared in carefully depicted magnificence on separate, large billboards (Figure 5). One helped advertise Lake Louise, “the home of the grizzly,” another Silvertip, a housing development and “tough” (but high class) golf course built on former grizzly bear habitat in Canmore. Had grizzly bears come of age as symbols of desirability and status, and might this be a fading image like the extirpated grizzly bear on the California State flag?

Most people have strong views about grizzly bears (Kellert 1994). To some they symbolize wild nature and all that is good about intact ecosystems where humans have chosen to manage our actions in order to maintain sensitive species and processes. To others they are undesired predators that sometimes injure, even kill people. To some, because of the land and resources grizzly bears need, they stand in the way of development. Today most people who visit Banff National Park and surround favor grizzly bear conservation (K. McDermid, Banff, Alberta, unpublished data). However, most people are unaware of the complexity of land use and grizzly bear management decisions necessary to provide for grizzly bear population maintenance. To evaluate how to maintain grizzly bears into the future in our rapidly developing region we need to understand the biology and ecology of the regional grizzly bear population and how past
human activities have affected grizzly bears. “The goal of carnivore conservation is to reverse declines in populations and to secure remaining populations in ways that gain enduring public support” (Clark et al. 2001). Designing and implementing successful grizzly bear conservation strategies necessarily involves broad public involvement and support because grizzly bear conservation has wide reaching land use effects that influence the actions of many people in the region.

Figure 5. Billboards on the Trans Canada Highway west of Calgary, Alberta. (credit: Herrero, S., 2004)

Strong arguments can be made for conserving and recovering remaining grizzly bear range and population numbers in our region. From a conservation perspective species have been classified according to a number of criteria (Table 1). Grizzly bears are exceptional because to some extent they meet all of these criteria; they are not perfect indicators for any. Grizzly bear conservation can support broader ecosystem conservation goals but it is only part of larger efforts to live sustainably with nature.

Table 1: Categories of conservation significance for species (Gittleman et al. 2001)

<table>
<thead>
<tr>
<th>Indicator species</th>
<th>Reflect critical environmental change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keystone species</td>
<td>Play a pivotal role in ecosystems</td>
</tr>
<tr>
<td>Umbrella species</td>
<td>Require large areas and if protected will necessarily protect other species</td>
</tr>
<tr>
<td>Flagship species</td>
<td>Popular species that attract attention</td>
</tr>
<tr>
<td>Vulnerable species</td>
<td>Most likely to become extinct (or extirpated)</td>
</tr>
</tbody>
</table>

Grizzly bears also fit the mold of extinction prone species (Woodroffe 2001). The history of many extirpated grizzly bear populations in North America is testimony to this. While grizzly bears have been extensively extirpated from portions of their former range in North America (Figures 1, 2, 3, and 4), they have never been reintroduced into an area where they once lived. This strongly suggests that landscapes and human activities often develop to a point where grizzly bears are no longer socially desirable even where habitat is still suitable to potentially support them. On the hopeful side, for those supporting grizzly bear conservation, some populations have naturally expanded to reoccupy former range (Pyare et al. 2004, Schwartz et al. In press). If we wish to continue to have grizzly bears and the ecosystems needed to support them in the Central Rockies Ecosystem, then the proven formula is to recover and maintain the current population.

LITERATURE CITED


1. The ESGBP and science-based grizzly bear conservation — S. Herrero

FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005
CHAPTER 2

STUDY AREAS
2. STUDY AREAS

Michael Gibeau and Saundi Stevens

CENTRAL ROCKIES ECOSYSTEM

The Central Rockies Ecosystem (CRE) is arbitrarily defined by a combination of geographic, biotic, and jurisdictional features. It is an area of approximately 40,000 km² straddling the Continental Divide of the Canadian Rocky Mountains. This broad area encompasses lands from the Columbia Trench to the Alberta foothills, and from the north end of Banff National Park to south of Kananaskis Country in Alberta and the Elk Valley in British Columbia (Figure 1). It is managed by a host of Federal and Provincial jurisdictions, with approximately 30% afforded some form of protected status, 60% in multiple use crown lands in Alberta and British Columbia, 10% in private ownership, and 1% Federal Reserve (Treaty) lands (Komex International 1995).

Figure 1. Study Area Central Rockies Ecosystem
The CRE is defined ecologically in the east, by the furthest extent of grizzly bear range. The Columbia Trench is the western boundary as it has intensive development, a north-south transportation corridor, and a wide river that combine to impede east-west bear movements in the area. One disadvantage of this arbitrary outline is that the grizzly bear population cannot be assumed to be closed. The boundaries, particularly in the north and south, are permeable to bear movements. Areas within the CRE available for grizzly bears varied considerably. Areas covered with rock, ice, water, bare soil and > 2500 m elevation make up a significant portion of the landscape. In the National Parks 48% of the landscape was unsuitable for foraging for grizzly bears. This contrasts with only 12% unsuitable on Alberta provincial lands, 21% unsuitable in Alberta’s Kananaskis Country, and 27% unsuitable on British Columbia provincial lands.

The landscape is generally described by 3 major ecoregions: montane (1,300 –1,600 m), subalpine (1,600 – 2,300 m) and alpine (>2,300 m). High rugged peaks with steep-sided narrow valleys characterize the mountains in the west and the climate is typically wet and cool. Dominant over story species in the montane are Western Hemlock (Tsuga heterophylla) or Western Red Cedar (Thuja plicata) in wet areas west of the continental divide or Douglas Fir (Pseudotsuga menziesii) and White Spruce (Picea glauca) in drier areas east of the divide. Sub alpine areas include Engelmann Spruce (Picea engelmannii) and Subalpine Fir (Abies lasiocarpa). Rugged mountains, steep-sided ravines and flat valley bottoms characterize the eastern mountains. The east side of the divide, with continental climate, is typically warmer and drier than the west slope. Montane regions of the east slopes are dominated by dry grasslands, wet shrub land, and forests of Lodgepole Pine (Pinus contorta), Douglas Fir, White Spruce and Aspen (Populus tremuloides). Subalpine areas are forested with Lodgepole Pine, Engelmann Spruce, Subalpine Fir and Subalpine Larch (Larix lyallii).

The climate in the region is characterized by long cold winters and short cool summers (Janz and Storr 1977). Average annual precipitation varies greatly with elevation; in Alberta, from <500 mm along the foothills and in the montane to about 800 mm in the upper subalpine and alpine zones (McKay et al. 1963). The eastern slopes in Alberta exhibit generally drier conditions than the west slopes in the Kootenays due to the rainshadow effect on the east side of the Rocky Mountains. January is the coldest month and July the warmest, with warm winter winds from Pacific air masses leaving the montane and foothills zones intermittently snow-free (Janz and Storr 1977). The east side of the divide, with continental climate is generally not as productive bear habitat as west of the divide with a moister climate.

For the last century in the CRE, humans have attempted to control natural processes that affect vegetation such as fire, insects, and disease. Historically, intermittent wildfires created a mosaic of forest types and ages, which supported a diverse composition of flora and fauna. However, fire suppression has created even-aged and even-canopied forest communities with a potentially dangerous buildup of fuel in the understory, and over much larger areas than in pre-Columbian times. This is leading to the heightened risk of a major fire that may burn hotter and spread farther than the frequent small historical fires. For grizzly bears, this means that large tracts of land are aging into late successional community types that do not produce the requisite food species of bears. Grizzly bears do best in post fire vegetation communities largely due to the need for fire, of two of its major food items, Buffaloberry (Shepherdia canadensis) (Hamer and Herrero 1987a, Hamer 1996) and Yellow Hedysarum (Hedysarum sulphurescens) (Hamer and Herrero 1987a,b, Hamer 1999). Except for horsetail (Equisetum arvense) in more mature forest communities, most important grizzly bear foods are found in open and seral communities (Hamer and Herrero 1987a). Many of these communities are the result of past fire events.

Management of the CRE is divided into four major governmental jurisdictions including National Parks (Banff, Yoho and Kootenay), Alberta’s Kananaskis Country, Alberta provincial lands and British Columbia provincial lands (Figure 2). Each jurisdiction encompasses a range of multiple land-use mandates to include urban and rural settlements, industrial and resource developments, tourism and recreation (Gibeau 2000, Theberge 2002).

Various components of ESGBP research focused on different portions of the CRE. The Bow River Watershed was the primary area of focus.
2. Study areas

— M. Gibeau and S. Stevens

FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005

BOW RIVER WATERSHED

The Bow River watershed of southwestern Alberta constituted the central core of the study area. This area is 11,400 km² of mountainous terrain 50-180 km west of Calgary (Figure 3). The area includes roughly 50% of Banff National Park (BNP) and all adjacent Alberta Provincial land known as Kananaskis Country. All study bears were initially trapped within this study area but were monitored over a much broader area of approximately 20,000 km² of the CRE. Neither jurisdiction permitted grizzly bear hunting although bears were exposed to hunting outside the Bow River Watershed. Differing agency mandates oversee preservation, industrial tourism, recreation, forestry, oil and gas extraction, mining, and stock grazing. Native councils, towns and municipalities, commercial developers, and residential owners further diversified land administration.

People accessed the area using primarily the Trans Canada Highway (TCH), a major transcontinental transportation route that bisects the study area northeast to southwest (Figure 1). The TCH, is a high-speed, high-volume (21,000 vehicles per day, average daily summer traffic volume; Parks Canada, unpubl. data) 4-lane divided highway through much of the study area. Forty-five km of the TCH through BNP has been
fenced to keep wildlife off the road. Wildlife crossing structures have been placed throughout the fenced section to facilitate movement across the highway (Clevenger and Waltho 2000). Several high speed, 2-lane paved roads serve as arterial transportation routes. Numerous 2-lane paved secondary roads complete the transportation system through most of the low elevation valleys. Traffic volumes on these arterial and secondary paved roads are high during the day (>300 vehicles per hour) but low at night (<50 vehicles per hour) which is significantly different than the continuous high volume on the TCH (Gibeau and Herrero 1998). There are few gravel roads in the study area. We know of no other area within occupied grizzly bear habitat in North America that has such an extensive network of high speed, high volume highways.

Human presence is widespread both within and outside of BNP. Three towns, Banff (population 7700), Lake Louise (population 2000) and Canmore (population 10,800) are world-renowned tourist destinations that attract approximately 4 million visitors annually. Calgary, a rapidly growing and affluent city of 960,000, is a half to 2 hour drive from most of the road access points in the study area. Developments, in addition to the towns that support tourism and industry, include a transcontinental railway, numerous hotels, campgrounds and picnic areas, 5 golf courses, 5 downhill ski facilities, and an extensive network of hiking, biking, and equestrian trails. The combination of a well-developed transportation system and elaborate infrastructure make the Bow River Watershed one of the most intensively developed landscapes in the world where a grizzly bear population still survives (Gibeau 2000, Herrero et al. 2000).

![Figure 3. Bow River Watershed Area Map](image-url)
LITERATURE CITED
CHAPTER 3
RESEARCH METHODS REGARDING CAPTURE, HANDLING AND TELEMETRY
3. RESEARCH METHODS REGARDING CAPTURE, HANDLING AND RADIOTELEMETRY

Saundi Stevens and Michael Gibeau

CAPTURE AND HANDLING

Between 1994 and 2002 we captured and radio-marked grizzly bears in the Bow River watershed and monitored their movements. Selection of areas to trap was based upon local knowledge of where habitat and terrain factors suggested we were most likely to capture grizzly bears. Trapping effort varied between years and was widespread throughout the entire 11,400 km² area. Most trapping was conducted during the spring when bears were concentrated at low elevations due to snow.

We captured grizzly bears in culvert traps or Aldrich foot snares as outlined in the protocol of Jonkel (1993). Bears were free-range darted from the ground and helicopter in special circumstances. We used snares predominantly in backcountry areas of Banff National Park and Kananaskis Country where vehicle access was prohibited. These sites were monitored once or twice daily, by foot or horseback. In vehicle accessible areas we used a combination of snares and culvert traps. Trapping effort was expended equally between remote areas and vehicle accessible areas. For bait, we used road-killed ungulates and beaver carcasses from local trappers. Some sites were pre-baited and monitored for activity before a snare or trap was set.

We immobilized captured bears using Cap-Chur dart gun equipment (Palmer Chemical Co., Douglasville, GA) and/or a jab-stick with Telazol at a dosage of 7-9 mg/kg (Taylor et al., 1989). We used Ketamine/xyazine at a ratio of 2 mg/kg for bears that required additional anesthesia (Taylor et al., 1989). The immobilized bear was given a complete physical exam then we obtained measurements, respiration, heart rates and rectal temperatures. When possible, we weighed the bear (to the nearest kilogram) by raising it with a pulley system attached to a weigh scale suspended from a tree or tripod. A premolar tooth was extracted and sent to Matson’s Laboratory, Milltown, MT, USA to determine age by cementum analysis. Numbered plastic ear tags (Allflex USA Inc. Dallas, Texas) were placed in each ear; males received yellow in the left ear and white in the right ear. Females received a white tag in the left ear and yellow in the right ear. Between 1994-96 we placed a 9x4 cm color coded ear streamer in the left ear of males and right ear of females to assist in visual identification. This practice was discontinued after abandoning the use of cameras, for which the visual ear markers were necessary, to try to estimate populations size. We extracted blood, from the femoral vein or artery, and tissue samples for both mitochondrial and nuclear DNA analysis as well as serum chemistry.

We fitted most individuals with either a VHF radio neck collar (Lotek Engineering, Newmarket, Ontario) or VHF ear tag transmitters (Advanced Telemetry Systems, Isanti, Minnesota). All radio collars were fitted with a breakaway cotton spacer (Hellgren et al. 1988) to ensure that collars would not be worn permanently. All transmitters were motion sensitive, changing pulse rate after 7 hours of inactivity to alert researchers if the transmitter was shed or the grizzly bear had died. Ear tag transmitters were programmed to turn on and off daily, and on a seasonal basis to maximize battery life. We placed two ear tag transmitters on some grizzly bears (one on each ear). One transmitter of the pair was programmed to begin functioning after the battery life of the first operating transmitter had expired. A small number of GPS collars (Televilt, Lindesberg, Sweden) were deployed in 2001 and 2002 in the immediate vicinity of Canmore and Lake Louise.

Captured bears were classified by sex and age class: adult (> 5 years old), subadult (2-5 years old), and yearling (1 year old). Cubs of the year were not marked in any way. There were few management related captures in the sample (2 subadult males, 1 subadult female, 1 adult female).

TELEMETRY AND MONITORING

We searched for collared bears at ± weekly intervals from the air, weather permitting, using a Bell Jet Ranger III helicopter or a STOL equipped Cessna 337 Skymaster. Aerial tracking followed the techniques of Mech (1983). Aerial fixes were established from an aircraft mounted GPS unit using the Universal
Transverse Mercator coordinate system. We also located bears from the ground on a daily basis where possible using a portable receiver, roof mounted omni-directional antenna and 3-element hand-held yagi antenna. In addition to systematic radio tracking, we conducted periodic 24-hour monitoring of individual animals at hourly intervals to obtain daily movement patterns. Rugged mountain topography limited our ground-based search for collared bears to areas adjacent to roads and trails. Radio locations were supplemented by occasional direct observation or reports from the public.

The status of bears was determined by a variety of methods. If a change in transmitter pulse rate was detected during regular flights, or from the ground, the site was investigated usually within one week and the dropped transmitter retrieved or the cause of mortality determined. Bears killed as problem wildlife, by hunters, and in some cases illegally were reported to and investigated by Conservation Officers. A suspected mortality was recorded when the radio signal from a bear that had been located in proximity to human settlement or camps disappeared prematurely.

Reproductive status of each female was determined by repeated visual observations from the aircraft while searching for radio collared bears during regular flights. Cubs were classified from their size and the known reproductive status of the female from the previous year. The maximum number of cubs observed was considered the litter size, although cubs lost very early in the season would not have been recorded. Mortality of cubs was assumed if they were no longer observed with their mother.

THE DATABASE AND NATURE OF THE SAMPLE

While trapping effort was expended equally between remote areas and vehicle accessible areas, over time, individual animals were targeted for collar replacement. Our recapture success varied depending upon capture vulnerability and the animal’s experience with trapping methods. While on the one hand it is necessary to follow individual animals for longer than the battery life of one radio collar to document long reproductive intervals, it potentially biases the data set by not re-sampling from the total pool of bears available. This could skew some results by weighting the radio telemetry sample towards bears whose circumstances or behavior favors longevity.

Aerial-based telemetry data, if collected from all study animals within the study area systematically, is an effective technique that does not bias location data except that only daytime locations are sampled. Our regular aircraft monitoring provided such a sample where each bear was searched for every flight. There were occasions however where not every bear was found every flight due to the difficulties of detecting radio telemetry signals in mountainous terrain. Budgets also constrained searching widely for bears whose signal had not been detected during regular monitoring flights. The ground based telemetry data is highly biased towards where workers could travel and signals could be detected easily. While this data is valuable for some analyses, it is not an unbiased representation of landscape use, is highly auto-correlated and was used cautiously. The GPS location data set is a better representation of fine scale movement although there are inherent biases in this data as well and we only had a small sample of GPS data. Research from other areas has found that GPS data is influenced by both shadow effect of mountainous topography and forest canopy closure. These blind spots create biases that are difficult to identify and correct for.

LITERATURE CITED

CHAPTER 4
GRIZZLY BEAR CAPTURE SUCCESS AND MORPHOLOGY
CAPTURE SUCCESS

The majority of captures were the result of intensive snaring effort (Table 1).


<table>
<thead>
<tr>
<th>Capture Method</th>
<th>Adult</th>
<th>Subadult</th>
<th>Yearling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert Trap</td>
<td>30</td>
<td>17</td>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>Snare</td>
<td>41</td>
<td>26</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>Free Range</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Heli-Dart</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Eighty-seven individual grizzly bears were captured in 129 capture episodes 1994-2003 (Table 2). The most intensive capture effort in 1994 yielded the greatest number of individual bears. Accurate records of our trapping efforts were kept only for 1994-1998. Alberta Conservation officers who did not keep records of trapping effort captured many of the bears between 1999 and 2003. Between 1994 and 1998 trapping effort totaled 1481 site-nights, with capture success ranging from 5 to 33 site-nights/capture. Three adult females with cubs of the year were captured during the study, in addition to 3 adult females with yearling cubs and 3 with two-year-old cubs.

Our sample of 87 individual grizzly bears was 52% male and 48% female. Fifty-eight percent of the male captures were adults, 40% were subadults, and 2% were yearlings. Sixty-seven percent of female captures were adults, 31% were subadults and 2% were yearlings. Because our capture program targeted specific individuals, especially females and subadults, we can make no comparisons of sex and age ratios between other grizzly populations.

We recaptured 34 individual bears on 42 occasions. Six of the 34 recaptures occurred in the same year as initial capture. Most recaptures were of adult males followed by adult females, subadult females, and lastly subadult males (Table 3).


<table>
<thead>
<tr>
<th>Year</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
<th>98</th>
<th>99</th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>366</td>
<td>n/a</td>
<td>189</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1481</td>
</tr>
<tr>
<td>No. grizzly captures</td>
<td>35</td>
<td>10</td>
<td>8</td>
<td>18</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td>19</td>
<td>13</td>
<td>129</td>
</tr>
<tr>
<td>No. individuals</td>
<td>27</td>
<td>10</td>
<td>8</td>
<td>18</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td>19</td>
<td>13</td>
<td>121</td>
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<tr>
<td>Site-nights/capture&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>37</td>
<td>n/a</td>
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</tr>
<tr>
<td>No. new individuals&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27</td>
<td>8</td>
<td>6</td>
<td>12</td>
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<td>4</td>
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<td>2</td>
<td>2</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>No. yearlings</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

<sup>a</sup> Site-nights/no. individuals
<sup>b</sup> New individuals are specified as those grizzly bears not previously captured.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Captures:</th>
<th></th>
<th>Recaptures:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Adult</td>
<td>Subadult</td>
<td>Yearling</td>
<td>Total</td>
</tr>
<tr>
<td>Male Captures:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>22 (25)\textsuperscript{a}</td>
<td>20 (23)</td>
<td>3 (4)</td>
<td>45 (52)</td>
</tr>
<tr>
<td>Female</td>
<td>26 (30)</td>
<td>15 (17)</td>
<td>1 (1)</td>
<td>42 (48)</td>
</tr>
<tr>
<td>Male Recaptures:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17 (41)\textsuperscript{b}</td>
<td>4 (10)</td>
<td>1 (2)</td>
<td>22 (52)</td>
</tr>
<tr>
<td>Female</td>
<td>11 (26)</td>
<td>8 (19)</td>
<td>0</td>
<td>19 (45)</td>
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<tr>
<td>Total:</td>
<td>76</td>
<td>47</td>
<td>5</td>
<td>128</td>
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</tbody>
</table>

\textsuperscript{a} Percent of 87 captures

\textsuperscript{b} Percent of 42 recaptures.

MORPHOLOGY

We observed significant difference in morphological measurements of males to females (Table 4). Adult males averaged 52.5 kg (35\%) heavier than adult females; subadult males averaged 19.5 kg (23\%) heavier than subadult females. Adult males were 17cm (9\%) longer than adult females; subadult males were 3cm (2\%) longer than subadult females. Males measured larger in chest girth than females of the same age classes (adults: 15\%, subadults 11\%). Foot pad sizes of males were greater than females of the same age class. The weights of all sex and age classes of grizzly bears obtained from our study (Table 5) did not differ significantly from those reported from the Swan Mountain area of Montana (Mace & Waller 1997). Other Eastern Slopes grizzly bear morphological measurements such as total length and girth are nearly identical to those reported from the Swan Mountains.


<table>
<thead>
<tr>
<th>Measurement\textsuperscript{a}</th>
<th>Male</th>
<th></th>
<th>Female</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>War (kg)</td>
<td>148,17,2,21\textsuperscript{b}</td>
<td>85,6,8,18</td>
<td>95,5,4,5,24</td>
<td>65,5,6,8,15</td>
</tr>
<tr>
<td>Zoological Length (w/tail)</td>
<td>190,6,6,22</td>
<td>160,5,6,21</td>
<td>173,5,3,2,21</td>
<td>157,6,14</td>
</tr>
<tr>
<td>Chest circumference</td>
<td>115,4,9,22</td>
<td>93,4,2,19</td>
<td>98,2,5,24</td>
<td>83,5,3,3,15</td>
</tr>
<tr>
<td>Front foot:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pad width</td>
<td>14,0,5,22</td>
<td>12,5,0,4,19</td>
<td>12,0,4,23</td>
<td>11,0,6,15</td>
</tr>
<tr>
<td>Pad length</td>
<td>15,1,4,22</td>
<td>11,1,5,19</td>
<td>10,5,1,3,23</td>
<td>9,5,1,2,15</td>
</tr>
<tr>
<td>Rear foot:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pad width</td>
<td>13,0,5,22</td>
<td>11,5,0,4,19</td>
<td>12,0,3,23</td>
<td>10,0,3,15</td>
</tr>
<tr>
<td>Pad length</td>
<td>21,5,1,5,22</td>
<td>18,5,1,4,19</td>
<td>17,5,0,9,23</td>
<td>17,5,1,2,15</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Measurements are from initial captures only.

\textsuperscript{b} Mean, SE, N. Scale weight given in kg, all other measurements in cm.
Table 5. Comparison of mean weight (kg) of grizzly bears from the Bow River Watershed, AB and Swan Mountains, MT.

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Male Adult</th>
<th>Male Subadult</th>
<th>Female Adult</th>
<th>Female Subadult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Slopes, AB</td>
<td>146</td>
<td>88</td>
<td>97</td>
<td>61</td>
</tr>
<tr>
<td>Swan Mountains, MT</td>
<td>156</td>
<td>81</td>
<td>88</td>
<td>60</td>
</tr>
</tbody>
</table>

LITERATURE CITED
CHAPTER 5
POPULATION CHARACTERISTICS
5.1 GRIZZLY BEAR DEMOGRAPHICS IN AND AROUND BANFF NATIONAL PARK AND KANANASKIS COUNTRY, ALBERTA

David Garshelis, Michael Gibeau, and Stephen Herrero

ABSTRACT
The area in and around Banff National Park (BNP) in southwestern Alberta, Canada, is one of the most heavily used and developed areas where grizzly bears (Ursus arctos) still exist. During 1994–2002 we radiomarked and monitored 37 female and 34 male bears in this area to estimate rates of survival, reproduction, and population growth. Annual survival rates of bears other than dependent young averaged 95% for females and 81–85% for males. Although this area was largely unhunted, humans caused 75% of female mortality and 86% of male mortality. Females produced their first surviving litter at 6–12 years of age ($\bar{x} = 8.4$ years). Litters averaged 1.84 cubs spaced at 4.4-year intervals. Adult (6+ year-old) females produced 0.24 female cubs per year and were expected to produce an average of 1.7 female cubs in their lifetime, based on rates of reproduction and survival. Cub survival was 79%, yearling survival was 91%, and survival through independence at 2.5–5.5 years of age was 72%, as no dependent young older than yearlings died. Although this is the slowest reproducing grizzly bear population yet studied, high rates of survival seem to have enabled positive population growth ($\lambda$=1.04, 95% CI = 0.99–1.09), based on analyses using Leslie matrices. Current management practices, instituted in the late 1980s, focus on alleviating human-caused bear mortality. If the 1970–80s style of management had continued, we estimated that an average of 1 more radiomarked female would have been killed each year, reducing female survival to the point that the population would have declined.

JOURNAL OF WILDLIFE MANAGEMENT 69(1):277-297; 2005

Keywords: Alberta, Banff National Park, Bow River Watershed, Leslie matrix, grizzly bear, population growth, reproduction, survival, Ursus arctos.

Human-caused mortality and habitat competition undermine grizzly bear populations, especially along the southern and eastern edges of their distribution (McLellan 1998). Today most adult grizzly bear mortality is human-caused even in the absence of hunting (Benn 1998, McLellan et al. 1999). Grizzly bear mortality is directly linked to the rate of contact with people and the potential lethality of each encounter (Mattson et al. 1996); the former corresponds to numbers and distribution of people, and the latter to their attitudes and behavior (Kellert et al. 1996). Along the edges of their range, grizzly bears more regularly encounter humans and human developments. The ability of grizzly bear populations to withstand these conditions is related both to the extent of human-caused mortality and the bears’ rate of reproduction, which can vary enormously across their range with varying availability of food (Ferguson and McLoughlin 2000). In general, grizzly bears show a lack of resilience, behaviorally and demographically, to anthropogenic disturbance (Weaver et al. 1996).

Alberta represents the southeastern edge of grizzly bear distribution in Canada (McLellan 1998). Although grizzlies once occupied all of Alberta, they were extirpated from the eastern grassland portions of the province by around 1890 (W. McCrory and S. Herrero. 1982. A review of the historical status of the grizzly bear in Kananaskis Country, Alberta. Alberta Fish and Wildlife Division, Calgary, Alberta, Canada). Today they are limited to roughly the western third of the province. Here, much of their primary range lies within the Central Rockies Ecosystem, encompassing BNP and adjacent Alberta provincial lands, and extending into British Columbia, including Kootenay and Yoho National Parks and adjoining lands under provincial jurisdiction (Benn 1998, Gibeau et al. 2001). Outside parks, grizzlies may be exposed to legal hunting, and they also face increasing pressures from land use activities associated with extraction of coal, oil, gas and timber, production of livestock and agricultural crops, and construction of new homes and roads. No reliable estimates exist for the present number of grizzly bears in Alberta, but they are categorized as may be at risk (Kansas 2002) and are being considered for reclassification as threatened.
Our study, part of the Eastern Slopes Grizzly Bear Project (ESGBP), began in 1994 in response to mounting development pressures and a dearth of information regarding the status of grizzly bears in and around the Bow River Watershed (BRW), the most intensively used portion of the Central Rockies Ecosystem (Herrero 1994, Herrero et al. 1998; Fig. 1). Previously completed ESGBP research involved grizzly bear mortality, movements, distribution, and habitat considerations (Gibeau 2000, Gibeau et al. 2001, Benn and Herrero 2002, Mueller et al. 2004).

In this phase of the ESGBP research we examined demographic attributes, including: (1) rates and causes of mortality, (2) reproductive rates, and (3) population growth rate. We used these results to evaluate current management policies and to develop recommendations for continued population monitoring and management. Our study was prompted by the concerns of management agencies related to maintaining non-declining grizzly bear populations in the face of increasing land use.

**STUDY AREA**

Our 11,400-km² study area, situated 50–180 km west of Calgary, in southwestern Alberta (51°N, 115°W), encompassed the watershed of the Bow River from its source in the Rocky Mountains to approximately where it meets the prairies. Gibeau et al. (2001) and Chruszcz et al. (2003) described the biophysical features of this area.

The area included roughly half of BNP and all of the adjacent Alberta Provincial land known as Kananaskis Country plus other Alberta Provincial land (Fig. 1). Kananaskis Country is a multiple-use area about half of which is designated as provincial parks and the rest as forest lands or recreational areas. Grizzly bear hunting was prohibited throughout the study area, but ungulate and carnivore hunting occurred outside
of BNP, and bears were exposed to hunting when they traveled outside the BRW. Under the authority of treaty agreements, native people also could kill bears whenever and wherever they chose, outside national parks. Less than 100 bears were thought to reside within the BRW (P. I. Ross. 2002. Update COSEWIC status report on the grizzly bear Ursus arctos in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, Canada). All study bears were initially trapped within this area, but were monitored over a broader area of approximately 20,000 km².

Human presence is widespread both within and outside BNP. Three towns, Banff (population 7,700), Lake Louise (population 2,000), and Canmore (population 10,800) are world-renowned tourist destinations that attract approximately 4 million visitors annually (Gibeau 2000). Calgary, a rapidly growing and affluent city of 900,000, is <2-hr drive from most roaded portions of the study area. Major developments in the study area include a transcontinental railway, numerous hotels, campgrounds and picnic areas, 5 golf courses, 5 downhill ski facilities, and an extensive system of hiking, biking, and equestrian trails. For an area that still supports a population of grizzly bears, the BRW has an unprecedented network of well-traveled roads (Gibeau and Herrero 1998), including the Trans Canada Highway (TCH), a major transportation route that bisects the study area (Fig. 1). In all, the BRW is one of the most intensively developed landscapes in the world where a grizzly bear population still survives (Gibeau 2000, Chruszcz et al. 2003).

Beginning in the late 1980s and continuing through this study, a host of measures were instituted to afford grizzly bears in the BRW greater protection from human-caused mortality (Parks Canada 1997, Herrero et al. 2001). Bear-car collisions were reduced by highway fencing, under- and over-passes, spacing opposing lanes of traffic, and lowering speed limits (Clevenger and Waltho 2000; A. P. Clevenger, B. Chruszcz, K. Gunson, and J. Wierczkowski. 2002. Roads and wildlife in the Canadian Rocky Mountain Parks – movements, mortality and mitigations. Final report to Parks Canada, Banff, Alberta, Canada). Aversive conditioning (e.g., rubber bullets), instead of killing or removal, was applied more often toward bears that frequented areas near human developments or roads. Educational programs were offered to visitors to help modify human behaviors that could put bears at risk, and in some cases people were restricted from using certain areas when bears were observed in the vicinity (Gibeau et al. 2002). In front-country areas, major changes were made in garbage storage and collection procedures (Benn and Herrero 2002), and some proposed developments were altered and others averted largely because of potential adverse effects on grizzly bears (Natural Resources Conservation Board. 1993. Decision report. Application to construct a recreational and tourist resort project in the town of Canmore, Alberta. Application 9103 – Three Sisters Golf Resorts Inc. Natural Resources Conservation Board, Government of Alberta, Edmonton, Alberta, Canada; Herrero et al. 1998).

METHODS

Field Methods

During 1994–2002 we captured and radiomarked 69 grizzly bears; 2 other bears initially radiomarked in 1993 also were included in our study. All but 1 bear were captured in either BNP or Kananaskis. Most trapping was conducted during the spring when bears were concentrated at low elevations. Traps were set in places that, judging from the habitat and terrain, appeared favorable for grizzly bears. As radio transmitters neared the end of their expected lifespan (1–3 years, depending on the type), bears were targeted for recapture and radio replacement; however, recapture success varied, so monitoring of some bears ceased before the end of the study.

We captured bears in culvert traps or Aldrich foot snares using protocols outlined by Jonkel (1993), or in some cases darted them from the ground or a helicopter. Trapping effort was expended equally between remote areas, accessible only by foot or horseback, and vehicle accessible areas. Four bears that were captured in management-related activities (i.e., problem bears) were also radiomarked and included as part of this study.

Bears were immobilized with Telazol® at 7-9 mg/kg (Taylor et al. 1989), and then measured and weighed. We recorded condition of the mammae (lactating, non-lactating but developed, undeveloped) and vulva (degree of swelling) of female bears as an indication of their reproductive status. A first premolar was extracted for age estimation (Matson’s Laboratory, Milltown, Montana, USA) based on cementum analysis.
We equipped individuals with either a conventional radiocollar (Lotek Engineering, Newmarket, Ontario, Canada) or an ear-tag transmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA). All radiocollars included a breakaway cotton spacer to ensure that they would not be worn permanently (Hellgren et al. 1988). Transmitters were motion sensitive, changing pulse rate after 7 hr of inactivity (mortality mode), indicating that the transmitter had been shed or the bear had died. We located radiomarked bears at approximately weekly intervals from the air and every 1–3 days from the ground. Rugged mountain topography limited ground-based searches to areas adjacent to roads and trails.

We obtained bear mortality data from 2 sources. If the pulse rate of a transmitter switched to mortality mode, we went to the site to conduct a ground search, and either located a dropped transmitter or a dead bear. In the case of a dead bear, we examined the carcass and the surrounding area in an attempt to determine the cause of death. Bears killed as problem wildlife, or by hunters (illegally, in some cases), were reported to, and investigated by, Conservation Officers, who later relayed the information to us.

We obtained information on cub production and survival through visual observations during radiotracking of adult females. Cubs (0–1 year old) were differentiated from older offspring based on their size and the reproductive status of the mother the previous year. We did not estimate ages of offspring older than cubs unless they were seen initially as cubs. Cub litter sizes were generally determined by late spring, so our data excluded cubs that died early in the season. Whole litters of cubs or yearlings (1-year-olds) no longer seen in the vicinity of their mother were considered dead. Similarly, we inferred death of individual offspring when a litter declined in number, and the reduced litter size was confirmed on later telemetry flights. We typically did not know the sex of offspring unless they were captured.

**Estimation of Survival**

We estimated survival rates of adult and subadult bears using the Kaplan-Meier (product-limit) estimator adapted for staggered entry (Pollock et al. 1989). We used half-months as the monitoring interval, and considered bears part of the monitored sample only when the signal from their radio transmitter could be detected on routine telemetry flights during that interval. As radios expired or fell off, the animals were censored. There was no indication that censoring was non-random (Tsai et al. 1999). Oftentimes, though, no definitive evidence existed that a radio had expired; we judged radios to have expired if near or after the end of their expected lifespan they could no longer be heard. If a radio signal disappeared well before the expected expiration of the transmitter batteries, and the bear previously had been located in proximity to an area of human activity, we recorded the bear as a suspected but unconfirmed human-caused mortality. These were treated in one analysis as deaths and in a separate analysis as censored observations (expired radio not associated with death). Radiomarked young bears still in association with their mother were entered into the survival analysis upon their independence, at whatever age (≥2 years) that occurred.

We calculated survival separately for each year of the study and tested for yearly differences using a log-rank test. Finding no yearly differences, we calculated an overall average annual survival in 2 ways. First, we calculated cumulative survival through the duration of the study, and exponentiated this by the inverse of the number of years of monitoring (i.e., 1/8.5). A problem with this method is that by chance a large proportion of animals could die during periods when the number of radiomarked animals was small, thus sharply reducing cumulative survival from that point forward. To avert this difficulty, and to increase sample size within monitoring intervals, we collapsed the data into a single calendar year (pooled years analysis), a common practice in studies of a variety of species (e.g., Sorensen and Powell 1998, Bennetts and Kitchens 1999, Conner 2001). We made separate estimates of survival for subadults (post independence from mother through 5 years old) and adults (≥6 years old) of each sex. Confidence intervals were calculated using equations from Pollock et al. (1989).

We tested whether survival curves differed by sex, age (adult versus subadult), area (inside versus outside BNP), and habituation to humans (habituated versus wary) using log-rank tests. We also evaluated the effect of each of these factors, as well as home range size (95% fixed kernel) as a continuous variable, by including them as covariates in a Cox proportional hazards regression. In all cases, cumulative and pooled
years analyses yielded significant differences for the same comparisons, so for clarity we report test statistics only for pooled data.

We classified individuals as park or non-park bears based on whether the predominance of their home range was within or outside BNP. All bears were easily categorized, as all home ranges were either predominantly in or outside the park. We classified bears as either habituated or wary following Mattson et al. (1992). Bears that maintained ranges near humans but did not tolerate close human presence were not considered habituated. There were no food-conditioned bears in our sample.

In an initial global Cox model, the interactions of sex–age and sex–habituation were significant, so we stratified proportional hazards regressions on sex. We obtained the relative risk of each factor (e.g., a risk ratio of 2.0x means a bear in this category was twice as likely to die) and the 90% CI associated with each risk ratio. Confidence intervals on risk ratios that did not include 1.0 indicated statistical significance (Riggs and Pollock 1992). We report risk ratios only when they were significant and when plots of hazard functions for the strata being compared appeared proportional (Riggs and Pollock 1992).

To assess the effects of different types of mortality, we categorized causes as either natural, human-caused accidental, or human-caused purposeful. We calculated cause-specific mortality rates by considering 1 cause at a time and treating deaths from all other causes as censored observations (Pollock et al. 1989). Bears that we suspected of having died when we lost contact with their radios were, in this analysis, considered purposeful human-caused mortalities; if these had been natural deaths there should have been no reason for their radios to stop functioning, and if they had been hit by a car or train, we would have learned of such.

We reviewed records of encounters between people and radiomarked bears, and judged, in each case, whether the bear would have been killed, had the policy toward grizzlies both within and outside BNP not been changed shortly before and during the early years of our study. We were able to forecast the outcomes of policies from a previous era because one of us (MLG) has worked as a warden in BNP since 1976 and thus has been directly involved in judgments regarding the disposition of problem bears.

**Estimation of Reproductive Parameters**

We determined ages of first reproduction only for females that were captured and radiomarked as subadults and monitored until they produced a litter. The minimum known age of first reproduction was 6 years old, so bears caught at or before this age could be included in this sample. Some first litters may have been lost before we detected them, but we were able to observe all surviving litters born to radiomarked females, and hence obtained a better estimate of the age that females produced their first litter that survived ≥1 year. Moreover, we could backfill (infer) the birth of surviving cubs 1–2 years previously for bears first captured at age 7 or 8 based on whether they were accompanied by cubs, yearlings, 2-year-olds, or no offspring at the time of capture. All surviving cubs remained with their mother for ≥2.5 years, so 7 or 8-year-old bears without offspring could not have previously produced surviving cubs.

We followed the procedure outlined by Garshelis et al. (1998) to estimate mean and median ages of first reproduction. This procedure entails calculating the proportion of females of each age that produced a first litter (or first surviving litter) among all monitored females of that age that had not previously produced. These proportions are then weighted by the proportion of females in the population available to have a litter at each age. This method is exactly the Kaplan-Meier time-to-event estimator typically used in survival analysis. All bears were entered into the analysis at age 6 (some being backfilled to this age) and were either observed to produce cubs or were lost from monitoring before they produced (right censored). Excluding censored records would have resulted in a low-biased estimate (Garshelis et al. 1998). We obtained confidence intervals by jackknifing, bootstrapping, and from standard Kaplan-Meier variance formulations (Hosmer and Lemeshow 1999). Whereas all these methods returned similar results, we present the most conservative (widest CIs), because small samples often yield underestimated variances in Kaplan-Meier analyses (Klein and Moeschberger 2003:100).

We used an analogous procedure to estimate the average interval between litters. However, unlike age of first reproduction, each female bear can have multiple litter intervals, so we treated each interval, rather than each female, as the sample unit. We examined each female’s reproductive record chronologically and tallied the number of years from production of a litter (or surviving litter) to production of another litter. If a
record ended during a period between litters (right censored), we used the data up to that point. We tallied
the number of monitoring periods of at least 1 year, 2 years, 3 years, and so on following a litter, and then
calculated the proportion of monitoring periods of each length that yielded a litter.

Mean cub litter size (after den emergence) was calculated using observed litters as the sample unit. We
included only litters that were first observed during their cub year. We made a separate calculation of
yearling litter size that included all yearling litters, regardless of whether they were observed as cubs.

We estimated survival of dependent young by following fates of litters of radiomarked mothers through
time. We treated individual cubs as the sample unit and estimated first-year survival as the number surviving
to 1 year divided by the number monitored. Unlike survival estimates for radiomarked bears, no censored
data existed with cubs because we were quite certain that their disappearance represented death. However,
we excluded cubs that were not monitored into their yearling year because their mother’s radio had expired or
she died. Hence, our estimate pertains to cubs that were not orphaned. We estimated yearling survival and
survival of older dependent young using the same procedure. Confidence intervals were obtained by
jackknifing.

We recorded ages that young bears became independent of their mother only for litters that were first
observed as cubs because we could not reliably determine the age of older dependent offspring. Because all
offspring in a given litter left at the same time, we used litter as the sample unit for estimating mean age of
independence. We assumed that independence from the mother occurred when all ≥2-year-old littermates
were not seen near their mother after mid-summer.

We estimated reproductive rates of each bear by dividing the number of female cubs it produced
(assumed to equal total cubs/2) by the total number of years it was monitored as an adult (≥6 years old).
When considering just surviving cubs, we included backfilled reproductive data, as explained earlier. On a
spreadsheet, with each row being the reproductive history of an individual bear, we aligned rows so that
columns represented the bear’s age, and then calculated age-specific reproductive rates as female cubs/adult
females. We used the same approach, with columns as years (1994–2002), to calculate year-specific
reproductive rates.

Overall reproductive rate (all adults, all years) was calculated by dividing the sum of female cubs produced
by the total adult bear-years (bears · years) of monitoring (method 1 of McLellan 1989). The mean
number of female cubs produced (among all adult females) divided by the mean number of years monitored
yields the same value (since the mean in both numerator and denominator is just the sum divided by the
number of adult females), and enables estimation of variance based on a Taylor’s series expansion:

\[ \text{Var}(c/y) = \left( \frac{\mu_c}{\mu_y} \right)^2 \cdot \left( \text{var } c/\mu_c^2 + \text{var } y/\mu_y^2 - 2\text{cov}(c,y)/\mu_c \mu_y \right), \]

where c is the number of cubs produced, y the number of years monitored, and \( \mu_c \) and \( \mu_y \) the means of these,
respectively (Mood et al. 1974:181). Confidence intervals were generated from this variance, as well as from
jackknifing and bootstrapping (10,000 resamplings), all of which returned nearly identical results.

**Estimation of Population Growth**

We estimated population growth (\( \lambda \)) using a deterministic Leslie matrix (Leslie 1945, 1948). We
arranged the Leslie matrix as 28 rows and columns representing each age from 0 (cubs) to 27 years old. We
considered 27 the age of reproductive senescence (Schwartz et al. 2003), which in the matrix analyses was
equivalent to all bears dying at this age. We arranged the data as occurring after the birth pulse (so-called
post-breeding census), given that the cub counts were made in spring and summer, after some mortality of
cubs (born in January or February) had already occurred. Consequently, we calculated the top row of
fecundities as the survival rate for bears of that age multiplied by the reproductive rate (female cubs/female)
of bears of the next age (Jenkins 1988, Noon and Sauer 1992, Williams et al. 2002). We conducted one
series of analyses in which all bears ≥6 years old were presumed to have the same average reproductive rate,
and a second set of analyses in which we assigned age specific reproductive rates for 6, 7, 8 and 9-year-old
bears, and combined 10–26 year olds.

The diagonal elements in the Leslie matrix represent survival rates. The first element (in the second row
of the first column) corresponded to survival of cubs to age 1. This value was derived as the product of cub
survival and adult female survival to account for cubs dying as a result of their mother dying, since first-year
cubs were typically not self-sufficient. Yearlings were also reliant on their mother, but we suspected that
some orphaned yearlings could survive on their own. In the absence of data on survival of orphaned yearlings, we made the assumption that their survival was only half that of yearlings raised by their mother. This assumption was made for completeness, but actually had little effect because adult female survival was so high that few yearlings (4–5%) were orphaned. Two-year-olds were a more complicated situation because some became independent at this age and others remained with their mother. We split 2-year-olds into these 2 groups in the proportions observed. We assigned the survival rate observed for older subadults to 2-year-olds that had become independent, either by leaving their mother or by their mother dying. The remainder were given the observed survival rate for dependent 2-year-olds (1.0). Although some bears continued to stay with their mother past age 2, we considered all 3–5-year-olds to have the same rate of survival. Likewise, all bears aged 6–26 were given the same survival rate.

An estimate of the asymptotic population growth rate (λ, at a stable age distribution) was calculated as the dominant eigenvalue of the Leslie matrix, using the POPTOOLS add-in (www.cse.csiro.au/cdg/poptools) to an Excel spreadsheet. We also used this software to obtain estimates of the ultimate stable age distribution (right eigenvector), sensitivities and elasticities of the matrix elements, mean lifetime reproductive output (R₀), and mean generation time (T), as explained by Caswell (2001).

We conducted matrix projections using various combinations of input parameters: survival of adult and subadult females based on only known mortalities versus survival including suspected mortalities; age-specific reproductive rates versus a single reproductive rate for all adults combined; and reproductive rates and rates of cub and yearling survival based on all litters versus just litters that survived their first year. These generated 8 separate estimates of λ, R₀, and T. We performed these analyses using multiple approaches to increase robustness of the results, as samples were not large so parameter estimates could vary with sampling error and assumptions regarding treatment of the data.

Confidence intervals on λ estimates were obtained both by bootstrapping (5,000 resamplings) and jackknifing. Although these 2 approaches generally yield equivalent results (Meyer et al. 1986, Shao and Tu 1995), we favored jackknifing because it deselects 1 bear at a time, enabling examination of each individual’s contribution to the population growth rate. We performed bootstrapping as a check on the jackknifing results because the distribution of jackknife pseudovalues was highly skewed. We also partitioned bootstrapped results to examine probabilities of the estimated λ indicating an increasing, decreasing, or stable population.

We extended the projection matrix to incorporate males, which we presumed would also live until 27 years old. Thus, we added 27 columns to the right and 27 rows beneath the previous matrix. Male age-specific survival rates were entered into the matrix on the same diagonal as females, in the lower right quadrant. We doubled the reproductive rate along the top row, because females were now producing male as well as female offspring; however, female cub survival was halved, and the other half became male yearlings. We considered males to have no effect on reproduction or survival of females, and hence no effect on population growth rate. We included them only to gauge their composition in the population at a stable sex-age distribution. This was analogous to the source (female) – sink (male) metapopulation models presented by Caswell (2001:90-92).

RESULTS
Survival

Survival rates were estimated from data obtained on 37 female and 34 male radiomarked bears. Fifteen females and 14 males were radiotracked as subadults, of which 8 and 4, respectively, were monitored into adulthood. Independent bears of every age, 2–27 years old, were included in the dataset. Twelve females and 4 males were monitored for at least 5 years. Females were monitored for an average of 44 months and males for an average of 21 months.

Seven females (5 adults, 2 subadults) were known to have died during the study, 1 in June and 6 during August–September. Two died of natural causes (1 killed by another bear in a berry patch, 1 fell down a cliff), 2 were hit by a train, 1 was shot by a person in self-defense, 1 was legally killed by a Treaty Indian, and 1 was translocated out of the study area where it was legally killed 11 months later on Treaty Indian lands (however, this bear was considered lost from the population when it was moved). The radio signals of 15 females were lost as a probable consequence of radio failure, and the records of these bears were censored at
that time. One other radio signal from an adult female disappeared during August for unknown reasons, possibly related to the bear having been killed.

Eleven males (6 adults, 5 subadults) were known to have died or were otherwise removed from the population. Only 1 died of natural causes (killed by another bear at an elk carcass), 1 was shot in self-defense, 1 was legally killed by a Treaty Indian, 1 was legally hunted, 2 were killed illegally, 3 were killed as nuisances, and 2 other nuisance bears were captured and removed from the population. Fourteen males were censored after probable radio failure, and 2 others were considered possible deaths after loss of their radio signals. All deaths and suspected deaths occurred during May–October.

Annual survival of adult females was estimated at 96% based on the 5 known mortalities and 95% based on the known and single suspected mortality, using either method of calculation (Table 1). Subadult female survival was estimated at 91–92%. Survival rates of adult and subadult females were not significantly different ($\chi^2 = 0.5–0.9$, depending on inclusion of suspected mortalities, df = 1, $P = 0.3–0.5$).

Adult male survival was estimated at 86–89%, depending on method of analysis and inclusion of a suspected mortality, and subadult male survival was estimated at 69–73% (Table 1). When suspected mortalities were included, subadult males had lower survival than adults ($\chi^2 = 4.0$, df = 1, $P = 0.04$).

Pooling adults and subadults of each sex, females had significantly higher survival than males (Table 1), either counting ($\chi^2 = 8.3$, df = 1, $P = 0.004$) or discounting suspected mortalities ($\chi^2 = 6.8$, df = 1, $P = 0.009$). Risk of mortality for males was 2.9–3.1x higher than for females (90% CI: 1.4–6.5). Just comparing adults, males had a 2.7x greater risk of mortality (90% CI: 1.1–7.2, $P = 0.07$).

Yearly survival varied from 89% to 100% for females and 55% to 100% for males. Yearly variation in survival of females and males were not related ($r = 0.07$, df = 8, $P = 0.85$) and no significant yearly effects were discerned for either sex, including or excluding suspected mortalities (F: $\chi^2 = 6.5–8.9$, df = 8, $P = 0.4–0.6$; M: $\chi^2 = 7.3–8.6$, df = 8, $P = 0.4–0.5$).

Among adult and subadult females (pooled), mortality due to purposeful killing by humans (2.7%, 95% CI: 0–5.4%) equaled mortality due to natural and accidental causes combined (2.7%, 95% CI: 0–5.4%). The rate of natural mortality alone was only 1.3% (95% CI: 0–3.3%). For males, purposeful human-caused mortality (17.7%, 95% CI: 8.1–27.3%) far outweighed natural mortality (3.0%, 95% CI: 0–7.6%). If purposeful human-caused mortality were eliminated and not compensated for by other forms of mortality, both male and female survival (combined ages) would increase to 97%. Including both purposeful and accidental events, humans were responsible for 75% of female mortality and 86% of male mortality.

Rates of human-caused mortality, both purposeful and accidental, did not relate to whether bears lived mainly in or outside the park, or the size of their home range. Neither of these factors added significantly to the Cox proportional hazards model. All natural and accidental human-caused mortalities occurred within BNP, but overall survival rates were similar between bears that lived within and outside the park, for both females (all ages: 94–96% within the park, range related to 1 indefinite mortality, $n = 23$; 94% outside the park, $n = 14$) and males (85–87% within, $n = 13$; 81–83% outside, $n = 21$).

Human-caused mortality of habituated ($n = 3$ of 6) and non-habituated ($n = 7$ of 28) male bears did not differ, although our sample of habituated bears was small. Among females, 31% of habituated bears (4 of 13) but only 4% of non-habituated bears (1 of 24) were known to have died of human-related causes; these samples also were small, but nevertheless suggested an increased risk of human-related death for habituated females ($\chi^2 = 2.7$, df = 1, $P = 0.1$).

We estimated that 6 more adult and 2 more subadult radiomarked females would have died, and 2 adults and 2 subadults that did ultimately die would have died earlier had the old system of bear management continued during our study. By contrast, we estimated that only 2 more adult and 1 more subadult radioed males would have died under this less protective management system. If this had occurred, then survival rates for adult females (91–92%) would have been similar to adult males (84–86%, $P = 0.3–0.4$), and subadult females (84%) would have been more like subadult males (65–69%, $P = 0.06–0.12$).
Table 1. Survival of radiomarked bears in the Bow River Watershed, Alberta, 1994–2002, based on Kaplan-Meier estimates cumulative through all study years versus all years pooled together as 1 year.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age⁵</th>
<th>Inclusion of known/suspected mortalities</th>
<th>No. individual bears⁶</th>
<th>Bear-years</th>
<th>Mortalities</th>
<th>Annual survival (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cumulative</td>
</tr>
<tr>
<td>Female</td>
<td>Adult</td>
<td>Known</td>
<td>30</td>
<td>115.8</td>
<td>5</td>
<td>0.96 (0.92–1.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Known + suspected</td>
<td>6</td>
<td></td>
<td></td>
<td>0.95 (0.91–0.98)</td>
</tr>
<tr>
<td></td>
<td>Subadult</td>
<td>Known⁷</td>
<td>15</td>
<td>18.7</td>
<td>2</td>
<td>0.91 (0.73–0.98)</td>
</tr>
<tr>
<td>All</td>
<td>Known</td>
<td></td>
<td>37</td>
<td>134.6</td>
<td>7</td>
<td>0.95 (0.92–0.98)</td>
</tr>
<tr>
<td></td>
<td>Known + suspected</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td>0.95 (0.91–0.98)</td>
</tr>
<tr>
<td>Male</td>
<td>Adult</td>
<td>Known</td>
<td>24</td>
<td>46.3</td>
<td>6</td>
<td>0.88 (0.78–0.95)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Known + suspected</td>
<td>7</td>
<td></td>
<td></td>
<td>0.86 (0.75–0.93)</td>
</tr>
<tr>
<td></td>
<td>Subadult</td>
<td>Known</td>
<td>14</td>
<td>14.2</td>
<td>5</td>
<td>—³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Known + suspected</td>
<td>6</td>
<td></td>
<td></td>
<td>—³</td>
</tr>
<tr>
<td>All</td>
<td>Known</td>
<td></td>
<td>34</td>
<td>60.4</td>
<td>11</td>
<td>0.85 (0.76–0.91)</td>
</tr>
<tr>
<td></td>
<td>Known + suspected</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td>0.82 (0.73–0.88)</td>
</tr>
</tbody>
</table>

⁵ Adult: ≥6 years old; subadult: post-independence from mother to 5 years old; all: adults and subadults combined.

⁶ Number of bears of all ages is less than adults + subadults because some individuals were monitored from subadult to adulthood.

⁷ No suspected deaths for subadult females; all deaths were confirmed.

³ Estimate reduced to zero by the death of all radioed bears during some sampling periods.
Reproduction

Reproductive Age. — Reproductive data were obtained from 30 female bears aged 6–27 years old during the study period. No bears <6-years-old produced cubs. We observed 143 bear-years of reproductive information on adult-age animals, and were able to infer another 12 bear-years of prior reproductive history.

Five of 11 6-year-olds, 3 of 4 nulliparous 7-year-olds, and 1 of 1 nulliparous 8-year-olds had their first litters, yielding an estimated mean age of first reproduction of 6.7 years (95% CI = 6.1–7.2, median = 6.6 years). The conventional estimate, counting just the 9 bears with observed first litters, was 6.6 years. The mean age of first production of a surviving litter was 8.4 years (95% CI: 7.2–9.8, range 6–12, median = 7.5 years), based on 13 bears whose first production of a surviving litter was observed, and 4 adults that were lost before their age of successful cub production could be ascertained (Table 2).

Litter Size and Survival.— Overall litter size averaged 1.84 cubs \((n = 38, 95\% \text{ CI}: 1.64–2.04, \text{ range} = 1–3)\); litters that survived their first year averaged 1.94 cubs \((n = 33, 95\% \text{ CI}: 1.73–2.15)\). These values include multiple (2–4) litters for some females; however, averages calculated from the mean litter sizes of each mother \((n = 23)\) were not appreciably different (1.79 for all litters; 1.90 for surviving litters). Yearling litter size averaged 1.84 \((n = 23, 95\% \text{ CI}: 1.58–2.10)\).

Table 2. Calculation of average age of first production of a surviving litter\(^a\) for female grizzly bears in the Bow River Watershed, Alberta, 1994–2002. The conventional estimate, derived by averaging the ages of observed first reproduction, is less than the estimate that includes females that were lost from the sample before they had a chance to produce.

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>No. nulliparous females observed</th>
<th>No. producing cubs</th>
<th>No. nulliparous females not observed at next age</th>
<th>Nulliparous females producing (%)</th>
<th>Percent of population available to produce 1(^{st}) cubs</th>
<th>Percent of population producing 1(^{st}) cubs</th>
<th>Age weighted by percent producing 1(^{st}) cubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>17</td>
<td>2</td>
<td>1</td>
<td>11.8</td>
<td>100.0</td>
<td>11.8</td>
<td>0.71</td>
</tr>
<tr>
<td>7(^b)</td>
<td>14</td>
<td>6</td>
<td>1</td>
<td>42.9</td>
<td>88.2</td>
<td>37.8</td>
<td>2.65</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>28.6</td>
<td>50.4</td>
<td>14.4</td>
<td>1.15</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>25.0</td>
<td>36.0</td>
<td>9.0</td>
<td>0.81</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>33.3</td>
<td>27.0</td>
<td>9.0</td>
<td>0.90</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>100.0</td>
<td>18.0</td>
<td>18.0</td>
<td>2.16</td>
</tr>
<tr>
<td>Sum</td>
<td>13</td>
<td>4</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
<td>8.38</td>
<td>8.38</td>
</tr>
<tr>
<td>Mean</td>
<td>7.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.38</td>
</tr>
</tbody>
</table>

\(^a\) Loss of whole litters that occurred early in the year were often difficult to detect, so mothers’ ages of first birthing were less certain than their ages of first production of cubs that survived at least 1 year.

\(^b\) Example calculation: 14 nulliparous 7-year-olds were observed, of which 6 (42.9%) produced cubs. Among those that did not produce at this age, 1 was lost from the observed sample, so only 7 nulliparous females were observed at age 8. Since the earliest age of first cub production was 6, 100% of females were available to produce at this age; 11.8% did so, so the remaining 88.2% were available to produce their first cubs at age 7; 42.9% of this 88.2% produced, so 37.8% of all females in the population produced first cubs at age 7. Multiplying 7 years x 37.8% yields the value in the last column (2.65). These are summed to obtain an estimate of the average age of production of the first successful litter. Tabulated values are rounded for clarity.

We obtained an accurate count of cubs early in the year for 4 mothers’ nonsurviving first litters: 3 were singles and 1 was twins, averaging 1.25 cubs/litter. First surviving litters were larger: 2 were singles, 10 were twins, and 1 was triplets, averaging 1.92 cubs/litter \((t = 2.37, \text{ df} = 15, P = 0.02, 1\text{-tail})\). Litter size was similar for 22 litters that were not the mother’s first surviving cubs: 6 were singles, 12 were twins, and 4 were triplets, averaging 1.91 cubs/litter.
Individual cub survival was 79% (42 of 53; 95% CI: 67–93%) considering all litters and 89% (42 of 47; 95% CI: 81–97%) for litters in which at least 1 cub survived. Cub survival was 60% (9 of 15 cubs) for mothers’ first litters and 87% (33 of 38) for subsequent litters ($\chi^2 = 4.7$, df = 1, $P = 0.03$). Of 10 known first litters, 5 (50%) were completely lost during the first year. Only 1 other complete litter was lost the first year, a single cub born to a 22-year-old female.

Yearling survival was 91% (29 of 32; 95% CI: 80–100%). The only 3 yearlings that died were ones that were part of a litter in which a sibling cub had already died, so in these 3 cases the original litter size of 2 was reduced to zero by the end of the second year. None of the 12 2-year-olds that stayed with their mother died, nor did any of the 5 dependent 3-year-olds or 2 dependent 4-year-olds. Overall survival of cubs until independence was thus cub survival multiplied by yearling survival, or 72% (95% CI: 55–91%) for all litters, and 81% (95% CI: 65–97%) for litters that survived, at least in part, their first year. Of 29 litters observed as cubs and for which we could determine their ultimate fate, 9 (31%) were entirely lost, 2 (7%) were reduced in size, and the rest (62%) survived intact.

All 6 cub litters that did not survive to their yearling year lived within BNP. Nevertheless, overall survival rate of offspring was similar for mothers inside and outside the park, as was the average number raised in each litter through at least their yearling year, and hence presumably to independence (1.3 offspring/litter for mothers in the park, 1.4 for bears outside the park).

Cubs from 6 of 12 litters (50%) left their mother at 2.5 years old, 3 left at 3.5, 1 at 4.5 and 1 at 5.5 years. Another litter stayed with the mother for at least 3.5 years, at which time the mother’s radio failed and we lost track of her and her offspring. The average age of independence from the mother (counting the litter censored at 3.5) was 3.4 years. Four of the 6 litters that left their mother at 2.5 years old were originally litters of twins, and 3 of the 6 litters that left at >2.5 years old were originally twins. We also observed family break-up for 5 litters of unknown age. Including these, litter size at independence averaged 1.88 ($n = 17$, 95% CI: 1.59–2.17); this value exceeds the mean cub litter size because it excludes litters that had been reduced to zero.

**Interval between Litters.**— The average interval between litters was 4.4 years (95% CI: 3.3–5.4) considering all litters and 4.5 years (95% CI: 3.4–5.6) including only litters that survived their first year. Ten bears produced litters at an interval of 3 or 4 years, and 3 produced litters that were 6–8 years apart. Two intervals of <3 years followed a litter of cubs that died; 1 mother had cubs the very next year (1 year interval) and another produced a new litter 2 years later. These 13 (or 15 if the last 2 are included) cases, involving 12 (or 13) individual bears, were the only completed litter intervals observed during our 9-year study. However, we also observed 23 open-ended intervals, some beginning with a litter but with no observed subsequent litter due to the mother’s death, failing of her transmitter, or the study ending (all right censored cases), and some where the mother was first radiomarked during an interval between births (left censored). We included only the right-censored open-ended intervals in estimating the average interval between litters (Table 3). Excluding non-surviving litters, the mean litter interval for bears within the park ($n = 7$ known and 8 open-ended intervals) averaged 5.0 years (95% CI: 3.1–6.9), compared to 4.0 years (95% CI: 2.9–5.1) for bears outside the park ($n = 6$ known and 3 open-ended intervals), but confidence intervals were wide and overlapping.

**Reproductive Rate.**— The population-wide reproductive rate was 0.239 (95% CI: 0.185–0.294) female cubs per 6+ year-old female/year considering all litters, and 0.213 (95% CI: 0.166–0.263) for litters that survived their cub year. Multiplying these values by the respective individual cub and yearling survival rates (calculated for all litters or just surviving litters), yielded (in both cases) an estimated rate of production of 0.172 female offspring reaching independence per adult female/year. That the same value was obtained whether considering all or just surviving litters stems from the fact that they were derived from nearly identical datasets, the former where mortality was considered in a single step, and the latter where whole litter loss and individual cub losses were considered in 2 separate steps.
Table 3. Calculation of average interval between surviving litters\textsuperscript{a} for female grizzly bears in the Bow River Watershed, Alberta, 1994–2002. The conventional estimate, derived by averaging the observed reproductive intervals, is less than the estimate that includes intervals that remained open when the female was last observed.

<table>
<thead>
<tr>
<th>Time period since last litter (yr)</th>
<th>No. periods observed</th>
<th>No. periods ending in cub production</th>
<th>No. incomplete periods not observed the next year</th>
<th>Observed periods ending in cub production (%)</th>
<th>Percent of all periods available to end in cub production</th>
<th>Percent of all available periods ending in cub production</th>
<th>Interval length weighted by percent producing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>6</td>
<td>1</td>
<td>40.0</td>
<td>100.0</td>
<td>40.0</td>
<td>1.20</td>
</tr>
<tr>
<td>4\textsuperscript{b}</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>50.0</td>
<td>60.0</td>
<td>30.0</td>
<td>1.20</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>33.3</td>
<td>30.0</td>
<td>10.0</td>
<td>0.60</td>
</tr>
<tr>
<td>7</td>
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<td>0</td>
<td>50.0</td>
<td>20.0</td>
<td>10.0</td>
<td>0.70</td>
</tr>
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<td>1</td>
<td>0</td>
<td>100.0</td>
<td>10.0</td>
<td>10.0</td>
<td>0.80</td>
</tr>
<tr>
<td>Sum</td>
<td>13</td>
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<td></td>
<td></td>
<td>100.0</td>
<td>100.0</td>
<td>4.50</td>
</tr>
<tr>
<td>Mean</td>
<td>4.23</td>
<td></td>
<td></td>
<td></td>
<td>4.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a} Litters in which ≥1 cub survived ≥1 year.

\textsuperscript{b} Example calculation: Of 24 periods observed following the birth of a successful litter, none ended in production of another litter after 1–2 years, 6 ended in cub production after 3 years, and 10 were not followed beyond 3 years. Four of 8 observed periods (50%) ended with a litter after 4 years. Since the minimum litter interval was 3 years, 100% of periods following a litter could have ended in cub production after 3 years; 40% did so, so the remaining 60% of the periods could have ended in cub production after 4 years; 50% of this 60% terminated in cub production, so overall 30% resulted in the birth of another litter after 4 years. Multiplying 4 years by 30% yields the value in the last column (1.20). These are summed to obtain an estimate of the average interval between successful litters.

Among adult bears monitored for a sufficient time to assess their individual reproductive rates, the poorest reproducers included 2 bears that produced no surviving cubs in ≥5 years (#40, 63), 2 that produced only 1 litter (1–2 cubs) in 7 years (#41, 62), and 1 that produced 2 litters totaling 3 cubs 8 years apart (#46; Fig. 2). All of these bears lived within BNP.

Significant variation was observed in the percentage of adults that produced litters each year (range <5% to >40%; \( \chi^2 = 17.3, \text{df} = 8, P = 0.03; 34\% \text{ of } \chi^2 \text{ due to zero reproduction in 1997} \)) and in yearly reproductive rates (which include litter size as well as the proportion of females producing; Kruskall-Wallis \( H = 17.4, \text{df} = 8, P = 0.03 \)). To some extent, though, yearly variations in reproduction may be an artifact of bears not being available to produce cubs in consecutive years, or even 2 years apart in this population, unless their whole litter was lost. When we excluded adult females that were not available to produce because they were rearing 0–2-year-old offspring, yearly differences in reproductive rates were less evident (Kruskall-Wallis \( H = 13.5, \text{df} = 8, P = 0.09 \)).

We detected no statistically significant age-related differences in reproduction among 6+ year-old bears. However, reproductive rates appeared especially high among 7-year-olds; 6 of 16 (38%) females monitored at this age produced a surviving litter, totaling 12 cubs or 0.38 female cubs/female (Fig. 2). At least 30% of females also produced litters at 6, 8, and 9 years old, but litter survival was lower. Grouping bears in age categories 6–9 (those producing mainly their first litters), 10–15, 16–21, and 22–26 years, 23%, 21%, 24%, and 20% of females, respectively, produced surviving litters/year.

Data were too sparse among old-aged bears to discern the probable age of reproductive senescence. One bear produced a nonsurviving litter at 22 years old and did not give birth during the following 2 years.
However, 2 other bears produced litters at age 23. One of these mothers was killed in mid-September, so we cannot judge what the fate of her cubs would have been. The other old mother successfully raised her litter of 2 cubs, which left her when she was 26 years old. Hence, her first opportunity for another litter was at age 27, but she did not produce then. Overall, the reproductive rate (counting just successful litters) for 20–26-year-olds (0.233 female cubs/female) was, if anything, higher than the reproductive rate for 10–19-year-olds (0.20). These data appear consistent with Schwartz et al.'s (2003) finding, from a compilation of studies of brown/grizzly bears, that senescence occurs at about 27 years of age.

Figure 2. Reproductive records (considering only surviving litters) of radiomarked adult female grizzly bears in the Bow River Watershed, 1994–2002, aligned by age. Age-specific reproductive rates (Σ female cubs/Σ adult females monitored; cub sex ratio assumed to be 1:1) are shown along the bottom, and individual reproductive rates (for bears that were monitored ≥4 years) are shown along the right side.

An average female bear in this population, which began producing cubs at 6.7 years old and lived to reproductive senescence, would give birth to 4.9 female cubs, of which 3.5 would survive to independence. However, most bears did not survive to the age of senescence. Based on matrix projections combining reproduction and survival, females produced, on average, only about 1.7 female cubs in their lifetime (Ro). The average time necessary to produce these cubs (generation time, T) was about 13.5 years (±0.5 years with varying assumptions regarding rates of reproduction and survival).

**Population Growth**

The range among all 8 estimates of $\lambda$ was narrow (1.035–1.043), indicating that variations in assumptions, methodologies, and inclusion or exclusion of 1 female whose fate was uncertain did not
appreciably affect our assessment of population status. Jackknifed and bootstrapped confidence intervals were nearly identical. In all cases, 95% CIs for \( \lambda \) included 1.0 (0.99–1.09). However, 90% CIs did not overlap 1.0 when the 1 female with an uncertain fate was not considered a mortality (1.00–1.09). When this bear was censored at the time of its disappearance, 93% of bootstrapped resamplings yielded a \( \lambda \) that was not declining (\( \geq 1.0 \)); when this bear was considered to have died, 90% of runs were not declining. Bootstrapping results indicated a 3–6% probability of estimated \( \lambda < 0.99 \), 9–13% probability of \( 0.99 \leq \lambda \leq 1.01 \) (fairly stable population), and 82–88% probability of \( \lambda > 1.01 \).

![Distribution of jackknifed pseudovalues of \( \lambda \) derived from data on radiomarked female grizzly bears in the Bow River Watershed, 1994–2002. Each female’s survival and reproductive record (considering only surviving litters) was deleted one at a time, and \( \lambda \) recalculated with a Leslie matrix. Each recalculated \( \lambda \) was multiplied by \( n-1 \) (\( n = 37 \) females) and subtracted from the full-sample estimate of \( \lambda \) multiplied by \( n \) to obtain pseudovalues (\( x = 1.04 \), 95% CI = 0.99–1.09). Individual bears in the tails of the distribution are identified (1 bear that was suspected of being killed is identified parenthetically).](image)

Six bears in the sample of 37 females were responsible for stretching the confidence interval below 1.0 (Fig. 3). Logically, these were all bears that died, and in particular included the only 2 subadult female mortalities that we observed. The adults included 1 bear (#40) that from age 15 to 20 produced no cubs, 1 bear (#26) that lost a 2-cub litter over a period of 2 years, waited 2 more years to produce another litter, then died while raising that litter, and a 22-year-old (#28) that was the only multiparous female whose cub litter did not survive a full year (Fig. 2). Conversely, adults at the other end of the spectrum, that elevated the estimate of \( \lambda \), included 2 bears (#30, 47) that successfully raised 6 cubs in 9 years with no mortalities, and 1 bear (#57) that gave birth at the minimum age of 6, successfully raised 2 cubs, and then gave birth to another 2 cubs 3 years after the first litter; this bear had the highest individual reproductive rate (Fig. 2).

The projected stable age distribution among females in this population included 12% cubs, 17% 1–2-year-olds, 19% subadults (3–5-year-olds), and 52% adults. The ratio of adult:subadult females in the projected population was 2.7:1. In our capture sample this ratio was 2.2:1. When males were added to the matrix they comprised 50% of dependent young (by definition), 43% of subadults, and only 23% of adults. The population growth rate was unaffected by the addition of males. However, if females had the same survivorship as males, the population would plummet (\( \lambda = 0.91–0.93 \)).

Summed elasticities for female survival (0.92) far exceeded elasticities for reproduction (0.08, averaged among various scenarios). The elasticity for adult survival (0.46) was twice that of independent subadults (0.23) and dependent young (0.23). However, adult female survival actually varied much less across years than survival of younger-aged bears, and survival overall was considerably less variable from year to year than reproduction (Table 4). This variability reduces the precision of the mean matrix from which these elasticities were derived. We recalculated \( \lambda \) from matrices in which each parameter was separately reduced to its lower 95% confidence limit, while holding all others constant, and found that whereas adult survival...
still had a large effect, annual variability in other vital rates had a greater effect on population growth than indicated by their relative elasticities (Table 4).

Table 4. Variation in vital rates and variation in population growth rates as a function of vital rates for grizzly bears in the Bow River Watershed, Alberta, 1994–2002. Elasticities (proportional change in \( \lambda \) in response to a proportional change in 1 of the vital rates) indicate a major influence of adult female survival. However, other parameters may be more variable, and thus have a larger effect on actual variation in \( \lambda \) than indicated by their elasticities.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>CV(^a) among years</th>
<th>95% CI(^a)</th>
<th>Decline in ( \lambda ) at lower CL(^b)</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All litters</td>
<td>0.24</td>
<td>62.4%</td>
<td>0.19–0.29</td>
<td>1.9%</td>
</tr>
<tr>
<td>Surviving litters(^c)</td>
<td>0.21</td>
<td>62.6%</td>
<td>0.17–0.26</td>
<td>1.8%</td>
</tr>
<tr>
<td>Cub–yearling survival</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All litters</td>
<td>0.72</td>
<td>31.4%</td>
<td>0.55–0.91</td>
<td>2.1%</td>
</tr>
<tr>
<td>Surviving litters(^c)</td>
<td>0.81</td>
<td>31.2%</td>
<td>0.65–0.97</td>
<td>1.6%</td>
</tr>
<tr>
<td>Subadult female survival</td>
<td>0.92</td>
<td>16.7%(^d)</td>
<td>0.79–1.00</td>
<td>3.5%</td>
</tr>
<tr>
<td>Adult female survival(^e)</td>
<td>0.96</td>
<td>4.8%</td>
<td>0.92–1.00</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

\( ^a \) CVs and CIs shown on table include both process and sampling variation, but only process variation affects \( \lambda \).

\( ^b \) Decline in estimate of population growth if this parameter is reduced to its lower confidence limit, while all other parameters remain fixed.

\( ^c \) Considering only litters in which ≥1 cub survived.

\( ^d \) High CV due to small sample size (only 2 of 9 years with survival <100%).

\( ^e \) Including only documented deaths (1 adult female with an uncertain fate was censored).

As a management guide, we calculated combinations of adult and subadult female survival rates that this population could withstand (i.e., combinations resulting in \( \lambda = 1.0 \)). If adult and subadult survival rates were the same, then an overall female survival of 91% would maintain this population (Fig. 4). In our 9-year study, this survival target rate would have been met even if 1 more radiomarked female had died every other year. If these additional mortalities had occurred, however, we would have been much less assured of the status of this population, as CIs around \( \lambda \) would have widely-overlapped 1.0, even if the point estimate was \( \sim 1.0 \). Our estimated survival rates under the old management system indicate that the population would be declining (\( \lambda = 0.98 \), Fig. 4) had efforts to reduce grizzly bear mortality not been instituted.

**DISCUSSION**

**Survival**

Females in the BRW had high rates of survival. Excluding human-caused mortality, survival of females after leaving their mother was nearly 99%. This matches what has been reported for some populations of polar bears (*U. maritimus*), where radiotelemetry data yielded higher estimates than previously thought possible (Amstrup and Durner 1995). It might seem illogical that survival could really be this high. In a telemetry study, if 20 bears were tracked from maternal independence at age 3 to age 23, at which point they all died, the calculated survival rate would be only 95% (20 deaths/[20 · 20 bear-years] = 5% mortality). Obviously this case is unrealistic, as even in the absence of human-caused mortality some bears would die before age 23, thus reducing survival below 95%. However, it is important to consider that in most telemetry studies, including ours, bears are not followed to their death at old age. The estimated survival rate is thus the rate up to but not including deaths due to old age. This is exactly what is needed for use in estimating population growth from a Leslie matrix, where reproduction is truncated at the age of senescence, effectively eliminating...
the old bears. Including mortality of post-senescent bears as part of an average rate for adult females would cause this estimate to be biased low, and thus under-rate the population’s growth rate. In our study, a 24-year-old female that was killed by another bear may have suffered this fate in part because of her advanced age, but she was nonetheless younger than our presumed age of senescence and accordingly was counted in the estimate of adult survival.

Another issue possibly affecting the estimation of survival is the loss of animals with low survival and retention of study animals with high survival, eventually leading to a biased sample (Zens and Peart 2003). The longer the study period, the more apt the sample is to become dominated by older and longer-lived individuals. If this occurred during our study, however, we should have noticed an increase in survival through time. This did not occur, probably in part because we continued to radiomark new bears of both sexes through the duration of the study.

Males had a lower rate of survival than females, due to higher mortality from human-related causes. Male home ranges averaged nearly 3x larger than those of females, and their risk of mortality was also about 3x greater, but home range size, independent of sex, did not explain an appreciable portion of the variation in bears’ susceptibility to mortality.

Seemingly contrary to our findings, Benn and Herrero (2002) reported that females constituted 80% of human-caused mortalities in Banff and adjacent Yoho National Parks during 1985–98. However, their data were obtained from park records of deaths and translocations, not telemetry, so bears that left the parks and were killed outside would not have been included. Among our radiomarked sample, 90% of human-caused mortalities were human-related events.}

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male mortalities (9 of 10) occurred outside BNP, whereas only 60% of the females (3 of 5) that died of human-related causes were outside the park. This likely accounts for the difference between our results and those of Benn and Herrero (2002), and also explains our inability to discern differences in survival between what we considered park bears and non-park bears; indeed, 3 males that we classified as park bears were killed outside the park.

Habituation to humans is another factor often associated with increased risk of mortality (Meagher and Fowler 1989, Mattson et al. 1992, Pease and Mattson 1999). About twice the percentage of females (35%) as males (18%) in our radiomarked sample were considered human-habituated. These females were somewhat more prone to being killed or otherwise removed from the population than females that did not frequent areas of human activity. However, heightened mortality among habituated bears was apparently much greater in the past, before management authorities cleaned up food and garbage attractants and began making a concerted effort to keep human-habituated bears alive (Benn and Herrero 2002).

Reproduction

Reproductive rates of bears in our study were among the lowest reported for this species. To some extent this is due to improved (less biased) methodology for estimating reproductive parameters, but to a larger extent the contrast is real.

Of the parameters that relate to a female bear’s productivity — age of first and last reproduction, litter size, and interval between litters — age of first reproduction appears to be most sensitive to local food conditions (Noyce and Garshelis 1994, Ferguson and McLoughlin 2000). Among interior populations of grizzly bears in North America, vegetational productivity (indexed by evapotranspiration) accounts for >90% of variation in age of first cub production (Ferguson and McLoughlin 2000). Our results, even based on the conventional (low-biased) estimator, suggest a slightly higher age of first reproduction (6.6 years) for this population compared to other interior populations at this latitude (5.5–6.1 years; McLellan 1994, Ferguson and McLoughlin 2000). Our estimated average age of first reproduction for surviving litters (8.4 years) was quite a bit higher than the age for all first litters, but this statistic has not routinely been reported in other studies so we cannot judge its comparability. McLoughlin et al. (2003) reported a similar average age of first production of a surviving litter (8.2 years; recalculated using our methodology) for grizzlies in the Canadian Arctic barren-grounds. An even older age of first successful reproduction (> 9 years) was observed in southwestern Alaska, but this was attributable to low survival of litters rather than delayed birthing (S.D. Kovach, U. S. Fish and Wildlife Service, personal communication).

The average interval between births in our study (4.4 years) was also greatly extended. Among only 11 bears in our study for which we observed at least 2 litters, 1 retained a litter for 4 years and had a known inter-litter interval of 7 years, and another raised a litter for 5 years and produced a second litter after 8 years (birthing in the first and last years of the study); these litter intervals equal the longest reported for this species. Craighead et al. (1995) observed 2 open-ended intervals of >7 years among 30 female grizzlies monitored over 11 years in Yellowstone National Park, Wyoming. Others (P. L. Clarkson and I. S. Liepins. 1993. Female productivity and cub survival of grizzly bears in the Anderson and Horton Rivers area NWT, 1987–92. Inuvialuit Wildlife Studies Program Report, Northwest Territories Department of Renewable Resources, Inuvik, Northwest Territories, Canada; Sellers and Aumiller 1994; R. A. Sellers, S. Miller, T. Smith, and R. Potts. 1999. Population dynamics of a naturally regulated brown bear population on the coast of Katmai National Park and Preserve. Final Resource Report NPS/AR/NRTR–99/36, National Park Service and Alaska Department of Fish and Game, Anchorage, Alaska, USA1999; S. D. Kovach, personal communication) observed notably long intervals between production of surviving (weaned) litters (Table 5), but these were due to low survival of litters. In our study all nonsurviving litters were either the bear’s first or last litter; hence the interval was approximately the same whether counting all litters or just surviving litters.

Mean cub litter size in grizzly bear populations has been reported to range from 1.6 to 2.5 (summarized by: LeFranc et al. 1987; Ballard et al. 1993; McLellan 1994; P. I. Ross. 2002. Update COSEWIC status report on the grizzly bear Ursus arctos in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, Canada). The mean litter size observed in our study (1.8 cubs) is near the low end.
of this range. Relationships between grizzly bear litter size and environmental productivity are less definitive than with age of first reproduction and litter interval, but still seem to show a trend (Stringham 1985).

The combination of long inter-litter intervals and small litter sizes yielded a low reproductive rate among adult females. Considering also the effects of delayed age of first birthing, bears in this population had the lowest potential lifetime cub production of any population yet studied. Given equal survival, adult females in other populations at this latitude or even much further north, would produce at least 50% more cubs over their lifetime (Table 5). It would appear that cub production in the BRW is limited by nutrition; however, we were unable to identify any habitat features within home ranges that explained variation in individual reproductive rates. Similarly, Aune et al. (1994) found that variation in reproductive rates of grizzly bears within their Montana study area did not conform to expectations based on their subjective assessment of habitat quality.

Wielgus and Bunnell (2000), who studied grizzly bears in a portion of our study area (Kananaskis) during the early 1980s, postulated that low reproduction was caused by a high turnover of adult males (from hunting), resulting in younger immigrant males displacing females from preferred feeding areas. That explanation was not upheld by our study. Hunting in this area has ceased, so although subadult male turnover (mortality) was fairly high, adult male turnover was low, yet the reproductive rate remained low (Table 1). Notably, although the reproductive rate that we observed was similar to that reported by Wielgus and Bunnell (1994a), the low rate in our study was due to extended litter intervals and somewhat delayed ages of first reproduction, whereas in their study the low rate was attributable to an unusually small litter size (Table 5). We cannot discount the possibility that males, in general, displaced females from better feeding areas (Wielgus and Bunnell 1994b), a situation that occurs even in unhunted populations of many species of bears (Garshelis and Pelton 1981, Derocher and Stirling, 1990, Joshi et al. 1995, Hwang 2003), but we think it is unlikely that males were ultimately responsible for the low productivity of females. The body condition index (Cattet et al. 2002) of BRW males, but not females, was lower than that of a more productive nearby grizzly population (Jasper National Park), although both sexes in BRW showed depressed levels of luteinizing hormone, which may have disrupted reproductive functions (M. R. L. Cattet, N. Caulkett, M. Gibeau, S. Herrero, J. Bahr, J. Van Cleef, and G. Stenhouse. 2003. Comparison of select health data between Eastern Slopes (ESGBP) and the Foothills Model Forest Grizzly Bear Projects (FMFGBP). Pages 13-16 in M. L. Gibeau and S. Stevens, editors. Grizzly bear monitoring in the Bow River watershed: a progress report for 2002. Parks Canada, Banff National Park, Alberta, Canada). We suggest that the low reproductive rate was most likely a result of limited nutrition, due to a low contribution of meat in the diet (Hamer and Herrero 1987; L. Felicetti, C. T. Robbins, S. Herrero, and M. Pinto, unpublished isotopic analysis of hair) — meat being directly linked to reproductive output in grizzly bears (Hilderbrand et al. 1999) — and also restrictions on where bears could feed without being disturbed by humans (Gibeau et al. 2001).

Whereas productivity among BRW females was low, survival of their young through the period of maternal dependency was at or above average compared to other areas. Cub survival was near the median rate (~75%) among studies from elsewhere in North America (Garshelis 2004), and was considerably higher (89%) when nonsurviving first litters were excluded. Yearlings also had a relatively high rate of survival (Table 5), as did older dependent young (none of which died). Although the lengthy maternal care exhibited by mothers in our study (averaging 3.4 years) diminished the frequency of births, the increased survival of offspring stemming from increased maternal care appeared to be an adaptive trade-off. Some other grizzly bear populations have employed the alternate strategy of higher reproduction but consequently lower survival of dependent young (e.g., Nunavut, Susitna, Table 5). These contrasting population strategies may be linked to differing sources of mortality of dependent young, which are, as yet, poorly understood.

**Population Growth**

Our combined estimates of survival and reproduction indicate that the grizzly bear population in the BRW has been growing by about 4% per year. This was an unexpected finding given that definitive population growth ($\lambda > 1$) has not been observed in any other grizzly population with a reproductive rate <0.3 (Table 5). Confidence intervals around our estimate of $\lambda$ allowed for the possibility that the population was actually declining. However, the width of these CIs was exaggerated by the inclusion of sampling variation in all of our parameter estimates, whereas only process (temporal, spatial, individual) variation actually affects population dynamics (Gould and Nichols 1998, White 2000).
Table 5. Demographic parameters* used to estimate population growth rate (\(\lambda\)) in studies of grizzly bears across North America, ordered by reproductive output (except that the 2 Kananaskis studies are placed together).

<table>
<thead>
<tr>
<th>Area b</th>
<th>Age 1st birthing</th>
<th>Age last birthing</th>
<th>Litter size</th>
<th>Litter interval</th>
<th>Repro ratec</th>
<th>Max. lifetime reproe</th>
<th>Survival</th>
<th>(\lambda)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>(\bar{x})</td>
<td>observed</td>
<td>assumedf</td>
<td></td>
<td></td>
<td></td>
<td>Point est.</td>
</tr>
<tr>
<td>Flathead, BC, Can.</td>
<td>5</td>
<td>6.4</td>
<td>20</td>
<td></td>
<td>2.3</td>
<td>2.8</td>
<td>0.42</td>
<td>8.7</td>
</tr>
<tr>
<td>Nunavut–NWT, Can.</td>
<td>5</td>
<td>8.1</td>
<td>26</td>
<td>25</td>
<td>2.2</td>
<td>2.8</td>
<td>0.41</td>
<td>7.7</td>
</tr>
<tr>
<td>Susitna River, AK, USA</td>
<td>4</td>
<td>5.6</td>
<td>26</td>
<td>26</td>
<td>2.1</td>
<td>2.8</td>
<td>0.36</td>
<td>7.7</td>
</tr>
<tr>
<td>Yellowstone, USA</td>
<td>4</td>
<td>5.6</td>
<td>25</td>
<td>20</td>
<td>2.2</td>
<td>2.8</td>
<td>0.35</td>
<td>7.5</td>
</tr>
<tr>
<td>Kuskokwim Mts, AK, USA</td>
<td>4</td>
<td>7.2</td>
<td>26</td>
<td>28</td>
<td>2.0</td>
<td>2.6</td>
<td>0.30</td>
<td>6.0</td>
</tr>
<tr>
<td>Selkirk Mts, USA–Can.</td>
<td>6</td>
<td>6.5</td>
<td>27</td>
<td></td>
<td>2.2</td>
<td>3.5</td>
<td>0.29</td>
<td>5.9</td>
</tr>
<tr>
<td>Cabinet–Yaak, USA</td>
<td>6</td>
<td>6.6</td>
<td>27</td>
<td>21</td>
<td>2.1</td>
<td>3.0</td>
<td>0.29</td>
<td>5.9</td>
</tr>
<tr>
<td>Swan Mts., MT, USA</td>
<td>4</td>
<td>6.0</td>
<td>23</td>
<td>25</td>
<td>1.6</td>
<td>3.0</td>
<td>0.26</td>
<td>5.5</td>
</tr>
<tr>
<td>Katmai, AK, USA</td>
<td>6</td>
<td>7.2</td>
<td>23</td>
<td></td>
<td>2.1</td>
<td>5.8f</td>
<td>0.25</td>
<td>5.0</td>
</tr>
<tr>
<td>Kananaskis, AB, Can.</td>
<td>4</td>
<td>5.0g</td>
<td>21</td>
<td>14</td>
<td>3.0</td>
<td>0.23</td>
<td>5.1</td>
<td>~78%</td>
</tr>
<tr>
<td>Banff-Kanan., AB, Can.h</td>
<td>6</td>
<td>6.7</td>
<td>23</td>
<td>26</td>
<td>1.8</td>
<td>4.4</td>
<td>0.24</td>
<td>4.9</td>
</tr>
</tbody>
</table>

* Blank cells indicate no information presented by authors and value not calculable from their report; ~ symbol indicates that study had insufficient data to estimate value directly.


c Age of last birthing assumed in Leslie matrix or Lotka equation, used to calculate \(\lambda\).

d Reproductive rate (female cubs born per adult female), often estimated from (mean litter size/2)/mean litter interval.

e Potential number of female cubs produced if a female lived until reproductive senescence, assumed to be 27 years in all cases (Schwartz et al. 2003); calculated as: \((27 – \text{mean age of first reproduction})\) · (reproductive rate).

f Intervals between weanings, not births; long intervals were due to frequent whole litter loss.

g Value recalculated; authors inappropriately added a half year to all ages.

h This study: reproductive data include nonsurviving litters, to be consistent with most other studies. However, estimates of age of first reproduction, litter interval, and reproductive rate are derived from methods that generally differ from other studies.
If the population had been growing at 4% per year, then it would have increased nearly 40% during the course of our study. Such an increase was not noticed. Unduplicated counts of females with cubs, a potential index of population size (Knight et al. 1995) showed no trend (M. L. Gibeau and S. Stevens. 2003. Grizzly bear monitoring in the Bow River watershed: a progress report for 2002. Parks Canada, Banff National Park, Alberta, Canada). Either this index was not sensitive enough to detect a trend, or our estimate of population growth was incorrect.

Population growth in the BRW would be less than we estimated if many of the added bears emigrated. Our estimate assumed the population to be geographically closed. Although we recognized this area as not being closed, we did not witness emigration of radiomarked females, and inasmuch as our estimate of population growth was derived only from females, male emigration would be inconsequential. Other studies of even more rapidly increasing grizzly-brown bear populations also observed limited emigration of females (Swenson et al. 1998, McLellan and Hovey 2001).

Stochasticity and density dependent factors, which were not included in our analysis, would depress the population growth rate below what we estimated (Benton and Grant 1999). An over-estimation of the age of reproductive senescence also would have inflated our estimate of $\lambda$. Others have generally assumed, more by convention than from empirical data, that females do not produce beyond 20–25 years of age (Table 5). We chose 26 as the last potential year of birthing, even though the oldest age of birthing in our study was only 23 years old (rationale explained earlier). Had we used 23 years instead, we would have obtained population growth rate estimates averaging 3.5%.

Variability among bears and non-representative sampling of this variability also could have biased our estimate of population growth. For example, under-representation of human-habituated bears (having lower survival) in the radiomarked sample would cause an over-estimate of $\lambda$ (Pease and Mattson 1999). However, we considered more than a third of our female sample to be human-habituated, and we still could barely discern a difference in survival between these bears and more wary bears because so few females died. Also, unlike the Yellowstone situation, where year-to-year fluctuations in a single food item had large effects on survival (Mattson et al. 1992), we observed relatively constant survival among females during this 9-year study.

We did observe significant year-to-year variation in reproduction, as well as an indication of possible differences in age-specific reproductive rates. This variability could result in an unstable age distribution, a violation of an assumption of the Leslie matrix. However, slight deviations from a stable age structure are not necessarily problematic. The overall $\lambda$ is just the weighted average of the growth rates of all the separate age classes, some strong, some weak (Sibly and Smith 1998). The real danger would be in deriving $\lambda$ from vital rates that were changing directionally through time, which was not the case in our study. Moreover, we obtained nearly the same estimate of $\lambda$ whether or not age-specific reproductive rates were included in the Leslie matrix. This finding coincides with that of Gilbert and Udevitz (1997), who modeled population growth for species with multiple-year reproductive cycles, including bears. In general, for many long-lived species, with undoubted yearly fluctuations in reproduction and/or survival (and hence age structures), studies have shown strong concordance between estimates of population growth derived from vital rates and from trend data (periodic counts or population estimates; Eberhardt 2002, Sandercock and Beissinger 2002).

Sensitivities and elasticities of the Leslie matrix transition elements indicated that the growth rate of the BRW population would be most affected by changes in adult survival. This finding has previously been reported for both hunted and unhunted grizzly bear populations (Wielgus et al. 2001). For long-lived animals in general, elasticities for adult survival tend to be highest (because adulthood spans such a long period of time), even though, as in our study (Table 4), juvenile survival and reproduction are usually more variable (Gaillard et al. 1998, Heppell et al. 2000, Sæther and Bakke 2000).

**MANAGEMENT IMPLICATIONS**

Our study yielded 2 especially noteworthy implications for grizzly bear management in the BRW. First, we found that this population is at the low extreme in terms of grizzly bear reproduction, so the potential for population growth is limited. Therefore, an attentive management program to limit human-caused mortalities is necessary. Second, we found that survival rates during our study, which were higher than under the
previous management system, seemed adequate to sustain this population; that is, the grizzly bear management program currently in place seems to be accomplishing its goal.

To assess whether managers are continuing to achieve their goal of sustaining a source (growing) population of grizzly bears, they could monitor survival rates using a sample of radiomarked females similar to ours. A survival rate of 91% should prevent population decline, although this target would be risky, as it does not consider either environmental stochasticity or sampling error. A safer goal would be to maintain the same rate of female survival that we actually observed in this study, overall about 95%, given that the lower 95% CL on this estimate was 91% (Table 1).

Survival also could be monitored without radiomarking, just by tallying known dead bears. Benn and Herrero (2002) did this while we conducted a companion telemetry study. They documented a decline in mortality, commensurate with dramatically improved human food and garbage management and more protective management policies. Using their data as a baseline representing positive population growth, management authorities could strive to ensure that total mortality did not increase beyond this. Radio-telemetry, though, would be a more reliable means of obtaining mortality data.

Whereas survival of grizzlies would likely decline under a more lax management program, increasing survival of grizzlies in the BRW beyond what has already been achieved is probably not feasible. Even in the high-profile grizzly bear population of Yellowstone National Park, USA, management efforts that successfully reduced human-caused mortality and enabled the reversal of a downward population trend (Eberhardt and Knight 1996) resulted in survival rates lower than what is necessary to sustain the population in the BRW (Table 5, Fig. 4).

Human-caused mortalities will likely increase in the future as the human population near the BRW continues to grow. The population of Calgary, the main urban center near the study area, increased by over 15% during 1996–2001, which, for that period, was the highest growth rate for a large urban area in Canada. This growing population places great demands for recreation, resource harvest, settlement expansion, transportation corridors, and other uses of the BRW landscape.

Upholding the level of survivorship necessary to sustain this population requires not only great effort and expense, but also sacrifices in terms of human use of the area. This is bound to create some animosity among potential users and raise questions about the need for ever-increasing measures to further protect grizzly bears (B. Cooper, J. Hayes, and S. LeRoy. 2002. Science fiction or science fact? The grizzly biology behind Parks Canada management models. Fraser Institute Critical Issues Bulletin, Vancouver, British Columbia, Canada). Those with that view may interpret our research results as evidence that the population is now growing and out of danger, and that accordingly, fewer restrictions on human development and activities are warranted.

We stress, however, that our results include many uncertainties, both in assessing short-term population trend, and, even more so, in forecasting future trends. Whereas our study was long enough to obtain data sufficient to produce adequate estimates of demographic parameters, it was but a snapshot in terms of grizzly bear population dynamics. For a small population like this, vulnerable to the impacts of varying human behaviors and environmental events, it seems only sensible to err on the side of prudence. So far, however, it appears that efforts designed to safeguard this population are working.

**ACKNOWLEDGMENTS**

We appreciate the major contributions in capturing and monitoring grizzly bears provided by M. Dupuis, M. Jalkotzy, R. Leblanc, C. Mamo, J. Paczkowski, I. Ross, J. Saher, T. Shury, S. Stevens, and M. Urquhart. We also thank J. R. Fieberg and J. G. Boulanger for statistical assistance, and R. B. Harris, S. D. Kovach, B. N. McLellan, S. D. Miller, C. C. Schwartz, and R. A. Sellers for helpful discussions and provision of unpublished data. D. R. Diefenbach and an anonymous reviewer provided useful suggestions for improvement of an earlier draft. We acknowledge Alberta Environmental Protection and Parks Canada for both technical and logistic support, and members of the Eastern Slopes Grizzly Bear Project Steering Committee for their guidance and financial support through all phases of this research. D. L. Garshelis was supported by the Minnesota Department of Natural Resources.
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5.1 Grizzly bear demographics in Banff Park and Kananaskis Country — D. Garshelis et al.
5.2 GRIZZLY BEAR DEMOGRAPHICS IN AND AROUND BANFF NATIONAL PARK AND KANANASKIS COUNTRY – POSTSCRIPT FOR 2003-2004

David Garshelis, Michael Gibeau, and Stephen Herrero

Following 9 years of intensive study (1994–2002) of grizzly bears in Banff National Park and Kananaskis Country, mortality monitoring was continued for another 2 years. A sample of 18 radiocollared females and 9 males were tracked from the ground during 2003–2004, including 3 females and 4 males that were caught in 2003. No new bears were added to the sample in 2004.

Two females and 3 males died in 2003 and 4 females and 2 males died in 2004. Four (36%) of these (2 males, 2 females) were natural mortalities, 3 caused by other bears and 1 by wolves. The 7 human-related losses (4 females, 3 males) were the result of collisions with a vehicle on the highway (n = 2), translocations due to nuisance activity (n = 3) or being shot (n = 2). Some collared bears were lost track of either because their collar dropped off or because they lived in remote areas where ground monitoring was not feasible. By the end of 2004, only 9 females and 1 male remained in the monitored sample.

Estimated survival for females (all ages pooled) based on these data was 88% (95% CI 74–100%) in 2003 and 71% (CI 47–99%) in 2004. Although confidence intervals on these estimates (based on the cumulative hazard; Link 1984) were wide, it appeared that these rates were well below the mean and confidence intervals of the previous 9 years (95% CI 91–99%, yearly range 93–100%). They were also below the minimal rate of survival (91%) necessary to sustain this population (i.e., to achieve λ = 1), given previous reproductive output.

Male survival, although not relevant to population growth rate, was also lower than normal in both these years (65% in 2003; 40% in 2004; 1994–2002 $\bar{x} = 81\%$, 95% CI 71–91%). Two peculiarities, though, detract from the reliability of the male estimates. First, one of the collared males that was killed by another bear had been orphaned as a cub (and was collared specifically as a result of this); had this not occurred, this bear likely would have been under the protection of its mother in May 2003, when it was killed at age 2. Excluding the data on this individual, estimated male survival was 77% in 2003 (within the previous CI). Second, the low estimate for 2004 was at least partially the result of small sample size: by June only 2 males were being monitored, 1 of which died.

The low rate of survival in these 2 years, at least for females, prompted this postscript to our paper. In the first 9 years, only 3 bears died of natural causes, whereas in these last 2 years, 4 natural mortalities occurred. Both females that died naturally (1 killed by a bear, 1 by wolves) were advanced in age (19 and 20 years old); although they were younger than the natural maximum lifespan for a grizzly bear (25–30+ years), they were likely more susceptible to being preyed upon than when in their prime. These bears had been radiocollared since 1994–95, so with each passing year of monitoring, they became increasingly likely to die. This potentially confounding problem of bears aging was not an issue during the 9-year study when new bears were added to the sample each year.

A second factor that likely affected survival was a widespread shortage of natural foods in 2004, which could have prompted more intra-specific strife, especially as bears competed for available foods. Low abundance of natural foods also may have prompted more bears to approach human food sources, where they were more likely to be shot, killed crossing a road, or translocated due to recurring nuisance activity. Three bears were translocated in these last 2 years, equaling the number translocated in the previous 9 years. Possibly, managers, who strove to keep these bears alive and in the population during the course of the study, felt less obliged to do so after the study officially ceased in 2002, and elected to translocate, rather than continue to deal with bears that were repeatedly involved in conflicts with humans.
Results from these last 2 years of monitoring reemphasize two important points discussed in our previous paper: (1) the effects of stochastic events (and possibly increased density-dependent effects) on grizzly bear demographics, and (2) the importance of continued monitoring for a population like this, where slight changes in bear or human behavior that influence grizzly bear mortality can tilt population trend from positive to negative.

LITERATURE CITED
5.3 GRIZZLY BEAR POPULATION DENSITY ESTIMATES WITHIN THE CRE

Stephen Herrero

In 1997, as part of the ESGBP, we did a low-budget attempt to derive a DNA-based capture/recapture estimate of grizzly bear abundance and density for the Bow River Watershed portion of the ESGBP study area (Sherry 1996, Proctor 1998). We used radio-telemetry locations to help correct for lack of closure for the study area. Despite this, the best estimate of density, 1.2/100 km², had a wide confidence interval (90% CI: 0.7 – 2.7/100 km²) (Proctor 1998).

Two prior studies, each using a similar sample of radio-collared grizzly bears, captured 1980–1984, generated population density estimates for grizzly bears living in and near Kananaskis Country. Carr (1989) used the Chapman-Robson mark-recapture technique to estimate the number of male grizzly bears. He assumed a sex ratio of 1:1 to estimate the number of females. Wielgus and Bunnell (1994) questioned the validity of this assumption and reported that for mostly the same sample from the same area the sex ratio was skewed towards males. As well Wielgus and Bunnell found immigration of males. This was taken as evidence for lack of closure of the population. Carr (1989) assumed he was sampling from a closed population. Wielgus and Bunnell (1994) estimated the mean annual density of bears by determining the mean annual number of bears present in the 97.5% multi-annual, composite home range of females. They suggested that all bears were accounted for in that 868 km² area but present no evidence to substantiate this claim. Both studies had methodological uncertainties and small samples. Neither presented confidence intervals around their point estimates of density. The Carr (1989) density estimate was 1.2 bears/100 km². The Wielgus and Bunnell (1994) estimate was 1.6 bears/100 km².

Despite methodological uncertainties, the reasonable convergence of the Carr (1989), Wielgus and Bunnell (1994), and Proctor (1998) population density estimates is worth noting despite their lack of precision and perhaps even validity. This convergence suggests very cautious use of the range of these 3 estimates, 1.2 – 1.6/100 km², not forgetting the large confidence intervals of the only study calculating CIs (Proctor 1998). In 2004, Stenhouse and others (Biologist, Foothills Model Forest, Hinton, Alberta, personal communication) conducted a DNA capture/recapture study in a north eastern portion of the CRE in Alberta. This study design improved substantially on that of the ESGBP (Proctor 1998). Results are not yet available but they should be more precise.

Even with improved research design there will remain challenges with extrapolating from one area to another regarding population density estimates and related point estimates of population abundance. One problem that will not easily be addressed is that extrapolation beyond a specific study area is only valid for areas of similar habitat productivity and grizzly bear demographics. For this and other reasons the ESGBP focused its efforts to understand population characteristics on demographic, long-term study of survival and reproduction of a large, radiomarked, random sample of grizzly bear cohorts in the Bow River Watershed (Garshelis et al. 2005). This has yielded precision and understanding regarding vital rates and their influence on population growth but has not allowed for a population density estimate or a point estimate of abundance.

A grizzly bear population density estimate also exists for the northwest portion of the CRE in British Columbia. DNA capture/recapture methods were used (Apps et al. 2004). Rigorous design and large sample sizes produced a population density estimate of 2.2 (95% CI 1.5 – 4.3)/100 km². Higher population density in this western slope of the Rockies area is predictable given more moisture and greater vegetation productivity. The higher west slope versus east slope density is paralleled by smaller home ranges for bears in the west slope portion of the CRE (Chapter 9, this report).

LITERATURE CITED


5.4 THE EASTERN SLOPES GRIZZLY BEAR PROJECT’S POPULATION VIABILITY ASSESSMENT FOR THE CENTRAL ROCKIES ECOSYSTEM

Stephen Herrero

ESGBP demographic analysis documented the dynamics of births, deaths and population growth for a random sample of different age and sex classes of 71 grizzly bears found in the Bow River watershed, 1994–2002 (Garshelis et al. 2005). This allowed for an assessment of demographic parameters for this population during this time period. It identified demographic variables that had the most influence on population dynamics. The demographic study was not intended to project future potential grizzly bear population status, another conservation management need. A Population Viability Assessment (PVA) forecasts extinction risk or persistence for a species at risk over time (Boyce 1992). This entails the use of models. No matter how much data one has regarding a current population, assumptions must be made regarding its’ future.

“Even though we often have insufficient data to perform PVA with statistical rigour, the model can be useful for framing our understanding of the principal processes that shape the species’ dynamics” (Boyce 1995). Early PVAs for grizzly bears incorporated demographic and genetic stochasticity but did not incorporate the possible effects of habitat change (Schaffer 1978). However, the close relationship between habitat and population condition is fundamental. “…Progress towards species conservation goals should be measured with consideration of habitat area, quality, and associated spatial relationships” (Roloff and Haufler 1997). All species depend upon their habitat for survival. PVAs therefore must incorporate habitat to be comprehensive. Indeed recent users of PVA have argued not only for the incorporation of habitat within PVAs, but also for its use as a supporting tool for ranking management scenarios, rather than formal estimations of extinction risk (Possingham et al. 2002).

Rapid and extensive changes have occurred regarding grizzly bear habitat in the Central Rockies Ecosystem (CRE) (Gibeau 1998, Gibeau et al. 2001, Chapter 13, this report). This has resulted in little secure grizzly bear habitat. Habitat is secure in areas where research suggests adult female grizzly bears can meet their daily needs with a low probability of encountering a person (Mattson 1993, Gibeau et al. 2001). Grizzly bears in the CRE live in one of the most developed, least secure, landscapes in North America where the species survives (Gibeau 2000, Herrero et al. 2000). Because of the extent of human activity and development in the CRE and the potential effects on grizzly bears, the ESGBP in 1999 undertook a PVA incorporating habitat considerations (Herrero et al. 2000). This was done in conjunction with the Conservation Biology Specialist Group (CBSG) of the International Union for the Conservation of Nature (IUCN). The initial work on the PVA was carried out in a retreat context over a 4 day period that brought together 87 people, including local researchers, other scientists (including expert research biologists and modelers), conservation and wildlife officers, land use planners, conservationists and business stakeholders. The PVA report is the only attempt by the ESGBP to project future conditions for grizzly bears at the scale of the entire CRE (about 40,000 km²) (Herrero et al. 2000).

The PVA model used was Vortex. The model identified 4 sub-regions in the CRE with the Trans-Canada Highway and the Rocky Mountains being unit boundaries internal in the CRE. Vortex allowed for different estimates of birth and death rates within each sub-region. CRE grizzly bears were assumed to be part of an open population. Therefore estimates of immigration and emigration were incorporated. Habitat quality and degree of human use and development were also incorporated into the model. Habitat-based models of grizzly bear probability of death were based on 2 things. First, most independent grizzly bears in the CRE die because humans kill them (Benn 1998). Second, human-caused deaths will occur at a rate governed by the frequency of encounters between humans and bears and the likelihood that a human will kill a bear during a given encounter (i.e. the potential lethality of contact) (Mattson et al. 1996). Probability of lethal contact is affected by policies of administrative jurisdiction, the most obvious being whether grizzly bear hunting occurs or not. Predicted variation in grizzly bear death rates were incorporated into habitat-based models derived from maps of jurisdictional boundaries, human facilities, roads and trails, human populations, and grizzly bear habitat productivity. The population model Vortex was used to predict the
probability of population decline or increase related to current levels. This was done by developing a series of stochastic simulation models of grizzly bear population viability. Probability of population decline or increase was chosen because all three major land managers in the CRE: Canada, Alberta, and British Columbia share the goal of having a non-declining grizzly bear population in the CRE.

Risk assessment projections depended most heavily on 2 demographic parameters: the percentage of adult females breeding and the rate of adult female mortality. Percentage of females breeding is influenced by age of first reproduction, senescence and interlitter interval. After the PVA was completed, subsequent demographic analysis of grizzly bears trapped in the Bow River watershed of Alberta (which is about one-fourth of the CRE) identified that these bears had the longest interlitter interval, latest age of first successful reproduction and lowest total reproductive output for any grizzly bear population studied in North America (Garshelis et al. 2005). Reproductive output is not likely to change very much since it is set by habitat productivity (Ferguson and McLoughlin 2000; also see Chapter 8, this report). Therefore, the bear population and its human managers must live with low reproductive output, at least in the Alberta portion of the CRE, and the knowledge that this significantly limits population resilience (Weaver et al. 1996). Adult female death rate, the other major variable influencing reproductive output, is more labile. The PVA modeling showed that a significant increase in the human population and related development would be predicted to cause further decrease in habitat security, increased contact between humans and female grizzly bears, an increased female grizzly bear mortality rate, and a related population decline (also see Chapter 13, this report).

The PVA workshop concluded that the impacts of humans on grizzly bear habitat and mortality must be reduced even while the numbers of humans in the region increase. It is unlikely that the number of humans coming into the area will decline dramatically. Therefore their impact on sensitive species such as grizzly bears will need to be addressed to prevent population decline. To do this the workshop recommended grizzly bear habitat restoration approaching 2% annually. Restoration would involve managing access and relocating human activities and facilities to less productive habitat to attain high survival rates for female grizzly bears. If this challenging task is not accomplished, and mortality rates for adult females increase, then population declines are inevitable. The workshop group recognized that there had to be a coordinated, joint management response from Alberta, British Columbia and Canada to manage the grizzly bear population and its habitat as a unit.

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CHAPTER 6
ADDITIONAL GRIZZLY BEAR MORTALITY ANALYSES
6.1 GRIZZLY BEAR MORTALITY IN THE CENTRAL ROCKIES ECOSYSTEM: INTRODUCTION

Stephen Herrero

Population dynamics of grizzly bears are a function of reproduction and mortality. Reproduction is difficult for managers to influence (Garshelis et al. 2005). It is driven by energy available to bears as food. Changes in foods available to bears naturally fluctuate between years and may influence reproductive output (Rogers 1976, Blanchard 1987, Stringham 1990). In the Central Rockies Ecosystem (CRE) during some years, berries, a primary energy source for grizzly bears, are abundant. During other years relatively little berry production occurs and grizzly bears forage more on less calorically dense roots (Hamer and Herrero 1983, Hamer 1985, Hamer and Herrero 1987). Other major changes in energy available to grizzly bears as food take place over longer time periods and are influenced by succession in vegetation communities. Dynamic changes occur in the decades after a fire or avalanche. While fluctuations in reproduction occur between years, population growth is much less sensitive to changes in reproduction than to changes in survival.

High female survival is fundamental to sustaining grizzly bear populations (Knight and Eberhardt 1985, Eberhardt 1990, Mace and Waller 1998, Schwartz et al. In press). Consistent with this broadly applicable finding, we found that the population trajectory for grizzly bears in the Bow River Watershed was most sensitive to changes in the survival rate for adult females (Garshelis et al. 2005). In the Bow River Watershed it would require a 15% improvement in reproductive output to be able to reduce the target survival rate by just 1% (Garshelis et al. 2005). This disproportionate contribution of survival to population growth or decline is highly likely to also be true for grizzly bears in the rest of the CRE.

Throughout our broader study area, the CRE, 75% and upwards of adult female and male grizzly bear deaths were caused by people (Benn 1998, Benn and Herrero 2002, Garshelis et al. 2005, Chapter 6.4 this report). This was true in the CRE in areas closed or open to grizzly bear hunting. Because of the diversity of situations that led to grizzly bear mortality in both hunted and unhunted areas, grizzly bear mortality is difficult to manage (Benn and Herrero 2002, Chapter 6.4, this report).

However, grizzly bear mortality in the Bow River Watershed was successfully managed 1994–2002. During this period there was >90% chance of grizzly bear population increase in the Bow River watershed (Garshelis et al. 2005). This occurred because wildlife managers were successful in keeping adult female mortality very low, with survival from year to year being 95–96%. However, had survival of adult females been less than 91%, which could have been caused by one more additional adult female mortality per year, the population’s trajectory would have been decreasing (Garshelis et al. 2005). Maintaining 1994–2002 grizzly bear survival rates in the Bow River Watershed will become more difficult because of the increasing human population and development (Chapter 13, this report). During 2003 and 2004 the estimated female (all ages pooled) survival rates were 88% (95%CI 72–100%), and 71% (95%CI 45–96%) respectively (Chapter 5.1, this report). While we have less confidence in these data, due to the ESGBP field research having ended in 2002 and subsequent samples being smaller and potentially biased, they are cause for concern because they were below the minimum rate of survival (91%) necessary to sustain the sampled population (maintain $\lambda \geq 1$) given previous reproductive output (Chapter 5.1, this report).

Human-caused grizzly bear mortalities are a function of the number of contacts with humans and the potential lethality of each encounter (Mattson et al. 1996). In theory both of these variables are amenable to management. In practice, management of mortality becomes increasingly more difficult with higher levels of human activities (Mattson et al. 1996). The non-protected portions of the CRE have extensive non-paved and paved road development as well as extensive off-road areas. The protected portions of the CRE in Banff National Park and Kananaskis Country have lower road densities but more high-speed, high-use volume highways. Access and road development are well known to be positively correlated with grizzly bear mortality probability (Mattson et al. 1987, Nagy et al. 1989, Mace et al. 1996).

When viewed in a North American context grizzly bears in the CRE are part of the southern and eastern fringe of the species’ distribution (McLellan 1998). Here too they coexist with a large and growing human population and because of this it is challenging to keep human-caused mortality at sustainable levels. Grizzly
bears in the eastern portion of the CRE in Alberta have very little secure habitat, areas where they can avoid contact with humans and meet their daily needs (Gibeau et al. 2001).

The Bow River Watershed, where we found a high probability of grizzly bear population growth 1994–2002, is only 11,400 km² of the approximately 40,000 km² Central Rockies Ecosystem. Almost no grizzly bear hunting occurs in the Bow River watershed. However, a significant portion of the northeastern part of the CRE (of which the Bow River watershed forms a part) is encompassed by Bear Management Unit 4C of Alberta. Grizzly bear hunting occurs in this BMU (Chapter 6.4, this report). Here recent research by an Alberta Government appointed group of population biologists showed a trend of declining age structure for female grizzly bear mortalities over time. The authors recommended, “In a conservative management approach it would be prudent to take steps to reduce overall man-caused mortality…until better population inventory data is available” (Stenhouse et al. 2003). Grizzly bear hunting also occurs in extensive, non-protected portions of the British Columbia portion of the CRE area (Chapter 6.4, this report). Population effects have not been subject to specific research (However, see Benn 1998, and Chapter 6.4 this report). Ungulate hunting, which has lead to self-defense killing of grizzly bears at carcass sites is also practiced throughout a large portion of the CRE (Chapter 6.6, this report).

Access by grizzly bears to human-related foods and garbage remains a fundamental cause of bears getting in trouble throughout the CRE. Such “food-conditioned bears” are more likely to be killed by humans or removed from the ecosystem (Herrero 1985, Benn 1988, Benn and Herrero 2002, Chapter 6.4 this report).

Demographic research in the Greater Yellowstone ecosystem suggests a source-sink dynamic with \( \lambda \geq 1 \) inside Yellowstone National Park and the Grizzly Bear Recovery Zone but \( \lambda \leq 1 \) outside the Recovery Zone (Doak 1995, Schwartz et al. In press). A source/sink structure may also exist within the CRE with protected areas like Banff National Park and Kananaskis Country being a modest source grizzly bear population and other areas like BMU 4C in Alberta possibly being a mortality sink. Portions of Banff National Park such as Lake Louise and the Trans Canada Highway have relatively high female grizzly bear mortality density, as do portions of Kananaskis Country (Chapter 6.5 and 6.6, this report). Rigorous scientific data is needed to determine if a source/sink population structure exists in the CRE. This is likely because grizzly bears found in the CRE, but outside of areas protected from grizzly bear hunting, have more potential sources of mortality and greater chance of encountering human activities and developments. Also relevant is that dispersal by sub-adult female grizzly bears from maternal home ranges occurs slowly and conservatively (McLellan and Hovey 2001). Thus population sink areas are only slowly re-occupied, and this only occurs if factors causing excessive mortality have improved.

In the CRE human-caused grizzly bear mortality limits grizzly bear population abundance (Garshelis et al. 2005). Therefore, an objective of the ESGBP was to document and analyze mortality and to identify management options regarding grizzly bear mortality in the CRE. In this chapter we present detailed numerical, spatial, temporal, and causal analyses of grizzly bear mortalities. Such analyses, when combined with demographic analyses such as we did (Garshelis et al. 2005), may be used to support a logical development of management priorities and actions with the aim of minimizing mortality of adult female grizzly bears, thereby supporting population goals. This approach is being successfully taken in the Greater Yellowstone Area (Gunter et al. 2004, Servheen et al. 2004). High survival of independent female grizzly bears is what has led to recovery and expansion of the Greater Yellowstone Area population (Knight and Eberhardt 1985, Pyare et al. 2004, Schwartz et al. In press). Ultimately, the appropriate mortality-rate target for independent female bears will depend on the risk that managers and the public are willing to incur relative to a population decline (i.e., \( \lambda < 1 \)) (Schwartz et al. In press).

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6.2 MORTALITY OF GRIZZLY BEARS IN THE BOW RIVER WATERSHED

Michael Gibeau

Persistence of grizzly bear populations is directly linked to the amount and type of human activity upon the landscape (Mattson et al. 1996). This pattern occurs not because grizzly bears are incompatible with human activities, but rather because humans conducting these activities are intolerant of grizzly bears (McLellan 1998, Woodroffe 2001). Consequently, human-caused mortality is the greatest threat to grizzly bear persistence today.

Garshelis et al. (2005) examined age and sex class survival rates among the research sample of grizzly bears in the Bow River Watershed (BRW). This is not the complete picture of mortality patterns within the study area as only the radio collared sample was considered. A more comprehensive overview of mortality has been systematically documented through annual reporting (Gibeau and Stevens 2003) of all known mortalities within the BRW since 1993 (Table 1). Known mortalities were compiled annually from Banff National Park and Provincial records, as well as follow up investigations by Conservation Officers of reports from the public. These are only the known mortalities. McLellan et al. (1999) estimated that as many as 50% of all mortalities may go undetected in areas where humans and grizzly bears share habitat.

Table 1. Age-sex class for known grizzly bear mortalities in the Bow River Watershed, Alberta, 1993–2002.

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Adult Female</th>
<th>Adult Male</th>
<th>Subadult Female</th>
<th>Subadult Male</th>
<th>Adult sex unknown</th>
<th>Subadult sex unknown</th>
<th>Male age class unknown</th>
<th>Female age class unknown</th>
<th>Total</th>
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<td>3</td>
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<tr>
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<td></td>
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<td>1</td>
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<tr>
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<td></td>
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<td>3</td>
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<tr>
<td>Unknown</td>
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<td>1</td>
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<td>Total: human-caused</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>Total: all deaths</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>39</td>
</tr>
</tbody>
</table>

Several trends in the data were evident with detailed categorization of the cause of death. Natural mortality accounted for 10% of all recorded deaths. All of these were within Banff National Park. There were no known cases of a natural mortality on Provincial lands in the 10 years of record keeping. Treaty Indians, who have the legal right to kill grizzly bears at any time anywhere outside the national parks, stood out as the single largest factor with 23% of known human-caused mortalities. Public safety action by
government officials and self-defense actions by citizens were the second largest factors, each accounting for 12% of the known human-caused mortality. All mortalities associated with self-defense actions by citizens were by hunters during the legal hunting season for ungulates.

Combining the data into broader categories again identified Treaty Indians as the single largest grizzly bear mortality factor (n=8) followed by government action (n=7), citizen action (n=6) and accidental (n=6). Sex specific data revealed that 41% of human-caused mortalities were female bears (n=14). It is generally accepted among management agencies that the maximum allowable human-caused mortality for female bears should not exceed 30% (Harris 1986). This statistic is further compounded by an additional 3 adult female bears translocated out of the ecosystem (essentially lost) over the 10 year period. This large proportion of female mortality in the sample is a serious management concern that was not identified in the analysis of the radio collared sample (Garshelis et al. 2004) but was previously identified within Banff National Park (Benn and Herrero 2002).

The wide range of causal factors in the mortality data set (table 1) demonstrates the complexity of management. Legal harvest, the single largest contributor in the Provincial mortality database, is a minor factor in the BRW. There is currently no effective dialogue with First Nations, the single major mortality source. Multiple sources of female mortality including public safety action by government officials, self-defense, highway and railway collisions, Treaty Indians, and translocations out of the ecosystem are collectively jeopardizing this population’s status with what is probably unsustainable female mortality.

LITERATURE CITED

Bryon Benn and Stephen Herrero

This is a summary, in which the methods section has been shortened, of a paper published in the journal *Ursus* (Benn and Herrero 2002).

ABSTRACT

We conducted spatial and temporal analyses to examine the relationship between access, changing grizzly bear management strategies, and grizzly bear (*Ursus arctos*) mortality from 1971–98 in Banff and Yoho National Parks, Canada. Grizzly bears are not legally hunted in these parks. We summarized mortality by cause of death, sex, age, and cohort. The annual number of grizzly bear deaths declined significantly between the periods 1971–84 and 1985–98. However, the female portion of this mortality increased from 50% to 80% between the same time periods. 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 500m of roads or 200m of trails. Eighty percent of these mortalities occurred below 2000m. Kills were concentrated at Banff townsites, Lake Louise, and along the Trans Canada Highway. Minimizing the human-caused mortality of adult female grizzly bears is crucial to maintain grizzly bear populations in Banff and Yoho National Parks. 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.


INTRODUCTION

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. 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).

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 grizzly 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 1988a, Mattson et al. 1996) consistently link the type and degree of human land use with grizzly bear mortality.

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, Proctor 2003).

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

**STUDY AREA AND METHODS**

The study area was Banff (6,836 km²) and Yoho National Parks (1,313 km²) (Fig. 1). We conducted spatial and temporal analyses to examine the relationship between access, changing grizzly bear management strategies, and grizzly bear (*Ursus arctos*) mortality from 1971–98 in these unhunted, protected areas. We summarized mortality data by cause, sex, age, cohort, and location related to development and elevation (Benn 1998). 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 500m and 200m were set around roads and trails. We stratified mortality data into 2 time 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 as cumulative changes in management made human food and garbage much less available to grizzly bears. Additional details can be found in Benn (1998) and Benn and Herrero (2002).

![Figure 1. The National Parks of the Central Rockies Ecosystem](image)
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). All human-caused grizzly bears mortalities in Yoho National Park occurred prior to 1981.

![Graph showing annual human-caused grizzly bear mortality by type for Banff and Yoho National Parks, 1971–98, (n = 119). PW = problem wildlife, H/RR = highway/railway, Other = research or unknown.]

Management actions and vehicle and train collisions accounted for 71% and 19%, respectively, of the 119 human-caused grizzly bear deaths. 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 15 vehicle and train collisions where the cohort was known, adult males accounted for 47%, dependent bears 33%, and adult and subadult females 20%.

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

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Cohort</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>adult</td>
<td>dependent</td>
<td>29.4 (35)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>dependent</td>
<td>adult female</td>
<td>16.0 (19)</td>
</tr>
<tr>
<td>unknown</td>
<td>subadult</td>
<td>adult male</td>
<td>15.1 (18)</td>
</tr>
<tr>
<td></td>
<td>unknown</td>
<td>subadult female</td>
<td>7.6 (9)</td>
</tr>
<tr>
<td></td>
<td>subadult</td>
<td>subadult male</td>
<td>1.7 (2)</td>
</tr>
<tr>
<td></td>
<td>unknown</td>
<td></td>
<td>30.3 (36)</td>
</tr>
</tbody>
</table>
Figure 3. Percent females in annual grizzly bear mortality. Numbers above the bars are the total mortalities with sex known for that year.

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.

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).*

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

* Total number listed is >95, as Highway mortalities at some townsites are tallied twice.
Figure 4. Grizzly bear mortality locations in relation to roads and trails in Banff and Yoho National Parks, 1971–98.
Eighty percent of all known mortality locations were below 1800m. The remaining 20% occurred between 1800m and 2100 m (Fig. 5).

Figure 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, 1375m; Castle Junction, 1430m; Lake Louise, 1540m; Chateau Lake Louise, 1740m; Skoki Lodge, 2135m; Moraine Lake Lodge, 1900m; Lake O’Hara, 2000m; Field, BC, 1250m.

Temporal Analyses

The mean annual number of mortalities declined significantly from 1971–1984 ( \( \bar{x} = 7.07 \) ) 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 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. 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 a
10 year period for any grizzly bear population. 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. Adult females with young and subadult grizzlies may have been more 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).

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 attempting to cross 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 1988b). 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. As precise measurements of population demographic rates are only now becoming available (Garshelis et al. 2005), 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, especially in the adult female cohort, 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 (Garshelis et al. 2004) 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.

**ACKNOWLEDGMENTS**

We thank D. Poll, B. Vroom, M. Gibeau, P. Paquet, A. Flegel, S. Jevons, and many from the Parks Canada Warden Service. We are also indebted to the Eastern Slopes Grizzly Project Steering Committee and the Faculty of Environmental Design, University of Calgary for funding and support. J. Nagy, C. White, and M. Gibeau reviewed and provided constructive comments on the manuscript.

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6.3 Grizzly bear mortality and human access: Banff and Yoho, 1971-98 — B. Benn and S. Herrero

FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005


Bryon Benn, Scott Jevons, and Stephen Herrero

ABSTRACT
We acquired grizzly bear mortality data from 1972–2002 and 1976–2002 for the Alberta and British Columbia (BC) study areas of the Central Rockies Ecosystem (CRE). We conducted spatial and temporal analyses to examine the relationship between access and changing grizzly bear and land use management practices on grizzly bear mortality. We summarized mortalities by cause of death, sex, age, and cohort. Human-related causes were the primary sources of grizzly bear mortality in both study areas. In Alberta, legally harvested grizzly bears accounted for 48% of 229 known human-caused mortalities, followed by management control (18%), illegal kills (16%), self defense kills (11%), and other causes of death (7%). In BC, 81% of all known mortalities were legally hunted bears followed by management control (16%) and illegal kills (3%). Total human-caused and harvest mortality, and percent females in the kill were within management guidelines for population sustainability in both jurisdictions. The total number of grizzly bears and the proportion of females killed both dropped following the implementation of limited entry hunting. Grizzly bears spend much of the year at lower elevations in both study areas, and roads and trails usually follow valley bottoms, potentially fragmenting riparian habitats. Eighty-six percent of 549 mortality locations in Alberta and BC fell below 2000m. Ninety percent of 185 known human-caused mortalities with accurate locations in Alberta and 56% of 369 in BC fell within 500m of roads and 200m of trails. Buffered roads and trails occupied 54% and 41% of the area of suitable habitat (<2400m) in each study area. Area-concentrated kills occurred along many drainages accessible by road or trail and around townsites and First Nations Reserves. Management of access, in particular of open roads, and human food and garbage, and educating hunters are critical issues with respect to managing grizzly bear mortality in the CRE. We present recommendations for reducing grizzly bear mortality.

INTRODUCTION
Grizzly bears in southern Alberta and adjacent British Columbia (BC) are part of a regional ecosystem in Canada called the Central Rockies Ecosystem (CRE, Figure 1). The CRE is experiencing intensive exploration and development of coal, oil, gas, and timber reserves. Cattle production, rural residential development, and outdoor recreation are also increasing, and hunting for large game, including grizzly bears occurs throughout much of grizzly bear range in Alberta and BC (Chapter 13, this report). Concomitant with this development, an infrastructure of roads has expanded into regions previously only accessible by non-motorized means (Chapter 13, this report). Motorized access roads are frequently implicated in contributing to grizzly bear mortality as 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 use, grizzlies, in particular established adult females, will cease crossing major transportation corridors (Gibeau and Herrero 1998, Proctor et al. 2002, Proctor and Paetkau 2004). As a result, the regional grizzly bear population is continuing to suffer from habitat loss and degradation, fragmentation of its range and potentially unsustainable mortality rates (Horejsci et al. 1998, Herrero et al. 2000, Stenhouse et al. 2003, Chapter 5.1, 5.2, this report).

Natural survival rates for adult grizzly bears not killed or removed by humans are consistently high (Knight and Eberhardt 1985, McLellan 1989, McLoughlin and Messier 2001), 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). Tracking natural mortality is difficult because habitat is often remote and heavily forested, and carcasses are soon scavenged. Natural causes are probably a minor proportion of adult grizzly bear mortality (McLellan 1994, McLellan et al. 1999). Data from around North America show that the number of recorded human-caused deaths far exceeds the known

Present attitudes towards the grizzly bear, a potentially dangerous animal (Herrero 1985) and competitor for food and space (Mattson 1990), challenge human-grizzly bear coexistence. Interagency planning for effective land use at the regional scale (Herrero 1995), 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).

Sustainable total and harvest mortality rates for bears have been estimated in computer-simulated populations (Bunnell and Tait 1980, Harris 1984, Harris 1986). Garshelis et al. (2005) were able to calculate the sustainable mortality rate, ≥91%, for grizzly bears in the Bow River Watershed, 1994–2002, based on 9 years of demographic data. Such data do not exist for the rest of the CRE. The threshold mortality rate where grizzly bear populations begin to decline can rarely be determined precisely. The determination of vital rates for grizzly bears requires long-term study deploying radiotelemetry, such as was done in the Bow River Watershed. Lacking this, the number of undetected mortalities is typically estimated by inference. McLellan et al. (1999) used the mortality data from radiocollared grizzly bears from thirteen studies in Canada and the United States to estimate the percentage of unreported human-caused mortality. They found that management agencies would have only detected between 45 and 51 percent of the human-caused mortalities of these radio-collared bears.

In this section, we analysed grizzly bear mortality from the CRE portion of Alberta (Alberta study area) for the 31-year period 1972–2002 and the East Kootenay region of BC from 1976–2002. Results are presented as summaries, and we discuss them temporally with respect to changing grizzly bear management strategies, and spatially to examine the effects of access on mortality in the bear population.

STUDY AREA

The Alberta and BC study areas encompass 21,150 km² and 10,960 km² of the CRE respectively (Figure 1). The area boundaries are defined by the limits of access maps and a digital elevation model. From the northwest corner, the Alberta study area leaves the Banff National Park boundary and runs east along 52° 15′ N latitude to its intersection with Alberta Highway 11. It follows Highway 11 to Rocky Mountain House, then south along Highway 22 to 50° 0′ N latitude. The south boundary follows 50° 0′ N to the Alberta-BC border. The west boundary follows the Alberta/BC border and the east Banff Park boundary to 52° 15′ N latitude. The digital elevation model extends further east and includes 3 mortalities that occurred east of the access maps. The area of Banff National Park is not included.

Commencing in the northeast, the BC study area leaves the Banff National Park boundary and runs west along 52° 0′ N latitude to the Rocky Mountain Trench. The west boundary follows the trench and Highway 93 south to 50° 0′ N latitude. It runs east along 50° 0′ N to the Alberta-BC border and turns north following the Alberta-BC border and the boundaries of Kootenay and Banff National Parks. The areas of Kootenay and Yoho National Parks are not included.

Elevation generally increases from east to west and north to south throughout the Alberta study area. The BC study area elevation increases from the valley bottom of the Rocky Mountain Trench east to the summits of the Continental Divide.
 METHODS

Grizzly bear mortality and translocation databases were supplied by Alberta Fish and Wildlife for the period 1972–2002. The British Columbia Ministry of Environment, Lands and Parks (BCMOELP) provided mortality records (Compulsory Inspection and Problem Wildlife files) for the period 1976–2002 but did not include information on translocated bears. Mortalities included dead bears, and in Alberta, bears translocated to more remote areas (generally north) that were not known to have returned, translocated bears that died in other jurisdictions and bears placed in zoos. We used all mortality data to summarize mortality by cause, sex, age and cohort, and a subset of mortalities with suitably accurate locations to conduct spatial analyses with respect to human access.

The conclusions reached and recommendations offered are based on the following three assumptions:

• the databases represent the minimum number of grizzly bear deaths and translocations;
• the stated goal of management agencies is to maintain or enhance the present population size and distribution of grizzly bears in the respective jurisdictions; and
• recreational hunting of grizzly bears is an acceptable practice, provided it is scientifically demonstrated to not cause population decline.

The following abbreviations for mortality types apply throughout this paper: LH legal harvest, PW management kill or translocation, IL illegal kill, SD self-defence, TI-H Treaty Indian hunt, TI-F Indian Reserve food attractant, Re research, H highway, AC accident.

Spatial Analyses

Locations of bear mortalities were referenced to the Universal Transverse Mercator (UTM) grid to the nearest 100 m in Alberta and 1000 m in BC, and included a descriptor such as a river, creek, or cultural feature. We interviewed past and present conservation officers (wildlife officers and park rangers) and
regional biologists to collect additional information about specific mortalities and their locations. We also interviewed as many successful Alberta hunters as we could locate and who were willing to participate.

For Alberta mortalities, “accurate” locations had a UTM designation to ±100 metres and matching geographic descriptor. “Reasonable” locations were described as being within some stated distance from a known road, trail, drainage or development. For practical purposes and due to the lower resolution (±1000 m), all BC mortalities with UTM were classified as “reasonable”. Mortalities with “estimated” and “unknown” locations were excluded from spatial analyses.

A human access map was created from the most recent and accurate spatial data for motorized and non-motorized access for the study area. The BC Ministry of Forests provided 1:20,000 scale motorized access data (updated 2001). For Alberta, 1:50,000 scale motorized access data were derived from Alberta Base Feature data. Data were updated using orthocorrected digital air photos, Indian Satellite imagery or GPS surveys.

Non-motorized access data were derived from a variety of sources including interpretation from orthocorrected air photos and Indian Satellite imagery, topographic maps, surveys using GPS, and existing digital materials provided by different agencies. Accuracy of these data varies from 5 to 25 metres (Scott Jevons, Alberta Community Development, Canmore, Alberta, personal communication).

Motorized access included railway lines and all roads open to the public and negotiable by 2-wheel drive vehicle. The trail layer included closed roads, utility corridors, and any other linear features accessible by ATV, hiking, mountain biking, or horseback.

We entered the access and mortality data into a geographic information system, ArcView GIS 3.2 (Environmental Systems Research Institute Inc.). For Alberta mortalities, zones of influence (ZOI) of 500m and 200m were set around roads and trails respectively. Buffer widths of 500m for motorized roads and 300m for non-motorized trails were implemented in the Yellowstone National Park grizzly bear cumulative effects model (Mattson 1999). As the Central Rockies Ecosystem generally has steeper and narrower valleys than Yellowstone, we are comfortable with 200m wide buffers for non-motorized trails in this forested mountain landscape.

We calculated the proportion of each study area that was considered suitable grizzly bear foraging and denning habitat (<2400 m, Gibeau et al. 2001) and the area of suitable habitat that occupied by road and trail buffers. Mortality locations were overlain on the access maps and the proportion of locations falling along buffered roads and trails calculated. 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 road and trail overlap were analysed within road buffers as roads were assumed to have a greater effect on mortality risk than trails.

We calculated the proportion of a sample of randomly generated points equaling 1 point per 5 km² (Nielsen et al. 2004) that fell within road and trail buffers. We tested the distribution of mortality locations against the randomly distributed points (expected values) with the single classification Goodness of Fit test (G-test with William’s Correction Factor).

Due to the lower resolution of location accuracy for BC mortalities (± 1000m), we set the ZOIs along roads and trails at 1000 m as we felt that narrower zones would fail to capture some mortalities that actually occurred within the buffers.

Non-sport mortalities were tallied with respect to proximity to townsites, landfills, commercial tourist operations and First Nations reserves. We assumed that bears were attracted to these areas by the presence of food and garbage (Weaver et al. 1986, Mattson et al. 1987). This assumption was supported by data from mortality records and discussions with bear managers.

### Elevation Analyses

The Digital Elevation Model (DEM) for the study area is a hybrid of two scales: 1:50,000 for Banff, Yoho and Kootenay NPs, and 1:20,000 for the provincial lands. The 1:20,000 DEM for the Alberta side and a portion of the BC side was provided by the Miistakis Institute. The remaining DEM (BC side) was constructed based on approximately 250 Themtatic Resource Inventory Mapping (TRIM) map sheets (digital contour lines). All of the component DEMs were pieced together and re-sampled to 30 meter pixel to match the resolution of Landsat TM imagery (Wierzchowski 2000).
We used the elevation of Alberta grizzly bear mortality locations to assess the effects of tourist destinations, town sites and other developments. This analysis was not performed for BC mortalities, as the potential range of elevations for each point was large. The placement of a location within 1000 m horizontal in a narrow valley could mean a vertical difference of greater than 1000 m.

**Temporal Analyses**

We stratified the mortality data into 2 periods (Alberta 1972–87 and 1988–2002; BC 1976–1989 and 1990–2002) to relate changes in mortality characteristics with changing patterns of human use and evolving management concerns and actions. Major change did not occur in any single year. Rather, a series of events in the 1980s led to a progressive modification in management practices. These actions included 1) increased efforts at communication and public education with respect to bears and improved garbage management, 2) closure of backcountry roads in Kananaskis Country in 1980–81, and 3) implementation of limited entry hunting (LEH) which was complete within the Alberta study area by 1987, and by 1982 in the BC study area. We recognized that it would take a few years for the bear population to adapt behaviorally to events such as the landfill and road closures.

**Seasonal Analyses**

Finally, we analysed cause of death by seasons. We used 3 seasons of biological importance to bears (April-July = pre-berry, July–Oct = berry, Oct–Dec = post-berry). Other times of year that affected grizzly bear mortality were the spring (April–May) and fall (September–November) hunting seasons and the peak of tourist activities (mid-June to mid-September).

**RESULTS**

**Alberta Summaries**

We collected 229 records of known human-caused grizzly bear mortalities from 1972–2002 on Alberta provincial lands within the CRE. These included 16 long distance translocations where we deemed the bears to have been effectively removed from the population. There were also three deaths of unknown cause and one natural mortality recorded in the database (Table 1).

The average annual human-caused mortality for the 31 year period 1972–2002 was 7.4 bears/year with the highest number of deaths occurring from 1980–87 (91 mortalities; 11.4/year; Figure 2). There were only 12 grizzly bear deaths recorded during the first 4 years, 1972–75, possibly due to less rigorous reporting of grizzly bear mortalities in these early years of record keeping.

Legally killed grizzly bears (LH) accounted for 48% (n=110) of all known human-caused mortalities followed by management kills or removals (PW 18%), illegally killed bears (IL 16%), self-defence kills (SD 10%) and all other causes of death (H, AC, RE 7%).

Table 2 shows the types of human activities and developments, and factors (e.g. firearms, food and garbage attractants) that contributed to 69 non-legal harvest kills in the Alberta study area. A minimum of 51 mortalities were associated with food attractants (31 food/garbage, 11 livestock, 9 hunter-killed carcasses)
Table 1. Causes and number of grizzly bear mortalities, and percentage of known human-caused mortality type in the Alberta study area of the Central Rockies Ecosystem, 1972–2002.

<table>
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</tr>
<tr>
<td>PW</td>
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<tr>
<td>SD</td>
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<td>11</td>
</tr>
<tr>
<td>AC/RE</td>
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<td>2</td>
</tr>
<tr>
<td>H</td>
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<td>5</td>
</tr>
<tr>
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<tr>
<td>total</td>
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<td>101</td>
</tr>
</tbody>
</table>

* LH legal harvest, PW management kill or translocation, IL illegal kill, SD self-defence, TI-H Treaty Indian hunt, TI-F Indian Reserve food attractant, Re research, H highway, AC accident

Figure 2. Known human-caused grizzly bear mortalities by year in the Alberta study area of the Central Rockies Ecosystem, 1972–2002 (n=229).
Table 2. Types of developments and land uses, and the number of incidents involving known attractants where grizzly bear mortalities occurred in the Alberta study area of the Central Rockies Ecosystem, 1972-2002 (n=69).

<table>
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<th>Location of kill</th>
<th>No</th>
<th>Attractant</th>
<th>Firearms present</th>
</tr>
</thead>
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<td>food and garbage (11)</td>
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<tr>
<td>Hiking trails</td>
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<td></td>
</tr>
<tr>
<td>Kananaskis Country Golf Course</td>
<td>1</td>
<td>probably introduced grasses</td>
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</tr>
<tr>
<td>Fortress Ski Resort</td>
<td>1</td>
<td>good habitat</td>
<td></td>
</tr>
<tr>
<td>Highway</td>
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<td></td>
</tr>
<tr>
<td>Townsites</td>
<td>6</td>
<td>open garbage (4), unknown (2)</td>
<td></td>
</tr>
<tr>
<td>Commercial Lodges</td>
<td>3</td>
<td>open garbage (2), unknown (1)</td>
<td></td>
</tr>
<tr>
<td>Ranching operations (private and</td>
<td>15</td>
<td>livestock (7), carcasses (4), granaries (4)</td>
<td>yes</td>
</tr>
<tr>
<td>First Nations Reserves</td>
<td>9</td>
<td>garbage, smokehouse, meat hanging</td>
<td>yes</td>
</tr>
<tr>
<td>Hunting (SD kills)</td>
<td>20</td>
<td>bear approached or charged (4), sloppy camp (4), bear shot off carcass (4), unknown (8)</td>
<td>yes</td>
</tr>
</tbody>
</table>

Sex and Age Analysis

We knew the sex, age and cohort of 212, 212 and 204 grizzly bears that died (all causes, Table 3). The overall sex composition of dead bears was 66% male and 34% female.

Table 3. Numbers and percentages of human-caused grizzly bear mortalities by sex, age and cohort in the Alberta study area of the Central Rockies Ecosystem, 1972-2002.

<table>
<thead>
<tr>
<th></th>
<th>No. of mortalities</th>
<th>Percentages of known</th>
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<tr>
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<td>97</td>
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<td></td>
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<tr>
<td>dependent</td>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td>subadult male</td>
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<tr>
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<td>18</td>
<td>22</td>
</tr>
<tr>
<td>ad fem</td>
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<td>10</td>
</tr>
<tr>
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<td>11</td>
</tr>
<tr>
<td>total</td>
<td>132</td>
<td>97</td>
</tr>
</tbody>
</table>
This included nine dependent bears (cubs of the year or yearlings) with sex recorded. Subadult males accounted for 37% of bears killed followed by adult males (20%), adult females (15%) and subadult females (15%). At least 9 family groups including 6 cubs of the year, 5 yearlings and 4 2-year olds were destroyed or translocated out of the study area as a result of management removals, illegal kills and self-defense kills, all prior to 1991. Thirty-three records had either no sex or age data.

Twenty-eight percent (27 of 97) of the LH mortalities were independent female bears. When all hunting related mortalities (IL, SD, TI-H) were included, the female proportion of the kill increased to 34% (51 of 97). The female portion of the kill associated with food attractants (PW, TI-F) was 32%.

**Alberta Spatial and Temporal Analyses**

Ninety-three percent (17,755 km²) of the Alberta study area was in suitable grizzly bear foraging and denning habitat (<2400 m). Zones of influence occupied 52% of the Alberta study area and 54% of the area of suitable grizzly bear habitat. Mortalities were not randomly distributed on the landscape. Ninety percent (166 of 185 with accurate locations) of human-caused grizzly bear deaths occurred within buffers along roads (34% north of the Bow R; 52% south of the Bow River) and trails (55% north of the Bow R; 41% south of the Bow River) compared to 51% of the sample of random points. This clumping of mortalities within the zones of influence was significant (G =125.773, df=1, P=0).

Of 37 bears killed outside of ZOIs, 33 were hunting related (24 LH, 6 SD, 3 IL). In addition, seven hunters interviewed stated that they initially observed the bear that they shot (outside of the ZOI) from a road or trail. Three management kills/removals occurred outside of road and trail buffers. Area-concentrated kills occurred along the upper Highwood valley, Bow Valley at Canmore, Evan-Thomas Valley, Ghost River, Waiparous Creek, Fallen Timber Creek, Panther River, Red Deer River near the Ya Ha Tinda Ranch, North Ram River, Clearwater River, and Job Creek (Figure 3).

Since 1987, the average annual mortality dropped to 6.5 deaths/year (n=97) from 8.3 deaths/year (n=132) during the early analysis period. This was predominantly the result of a 74% decline in LH mortalities during 1988–2002. During this same period, management removals more than doubled from the 1972–1987 period. Deaths of independent female bears (all human causes) declined from 38% during the early period, 1972–87, to 29% from 1988–2002.

**North of the Bow River**

Legal hunting accounted for 110 of 185 mortalities north of the Bow River valley. The total number of mortalities dropped by 42% (7.3-4.5 deaths/year) into the 1988–2002 period and legal grizzly bear kills declined by 74% (5.4-1.5 deaths/year). Causes of mortality related to non-grizzly bear hunting (SD, IL, Ti-H) also declined slightly (1.5-1.3 deaths/year) following the implementation of LEH. Mortality types associated with food attractants (PW, TI-F) increased substantially (0.7-1.2 deaths/year) into the later period.

The percentage of female bears in the overall legal harvest averaged 28%, declining from 31% to 19% from the 1972–87 to the 1988–2002 period. Thirty-eight percent of the non-LH mortality was female bears, with 47% and 31% occurring during the early and late periods respectively.

**South of Bow River**

Causes of mortality related to hunting species other than grizzly bears (SD=10, IL=10, TI-H=3) accounted for 51% of all human-caused mortalities south of the Bow River. This was followed by management kills/removals and other food attractant (TI-F) related mortalities at 40%, and other causes (AC, RE, H) at 9%. Grizzly bear hunting was only legal within Kananaskis Country in 1987, and resulted in the one legally hunted grizzly in the study area south of the Bow River.

Human-caused grizzly bear deaths more than doubled (0.9-2.1 deaths/year) in the 1988–2002 analysis period versus the 1972–1987 period. Hunting related mortality types (IL, SD, TI-H) exhibited a minor increase (0.7-0.9 deaths/year) in the later period, while PW and TI-F kills increased five-fold (0.2-1 death/year). Other causes of mortality (AC, RE, H) showed an increase of 1 grizzly bear death into the later period.
Females accounted for 65 and 38% of the non-LH mortalities south of the Bow River during the 1972–87 and 1988–2002 periods respectively. However, 60% of these mortalities between 1997–2002 were female.

Figure 3. Grizzly bear mortality locations in the Alberta portion of the Central Rockies Ecosystem from 1972–2002.
Elevational Analysis

Elevations were determined for 180 grizzly bear mortality locations in the Alberta study area (Figure 4). Treetline averages approximately 2210–2270 m (7200–7400 ft) along the eastern slopes of the Rocky Mountains.

Forty-four mortality locations south of the Bow River ranged from 1200–2300 m (4240–7500 ft) and 91% occurred below 2000 m (6520 ft). Major valley bottom elevations south of the Bow R. range from approximately 1350 m (4400 ft) on the eastern edge of the study area and in the Bow Valley to 1820 m (6000 ft) at the high point along the Smith-Dorrien Road and 2220 m (7240 ft) at the Highwood Pass.

Base elevations of major river valleys (e.g. Red Deer R., Clearwater R., James R.) north of the Bow R. range from approximately 1350 m (4400 ft) in the east to 1700 m (5540 ft) at the Banff National Park boundary. Eighty-five percent of 136 grizzly bear deaths ranging from 1000–2300m (3260–7500 ft) north of the Bow River occurred below 1800m (5870 ft). Only 2 human-caused mortalities in the Alberta study area occurred above 2100m (6850 ft).

Seasonal Analysis

Of 116 dated non-sport grizzly bear mortalities, 30 (26%), 58 (50%), and 28 (24%) took place in the pre-berry, berry (mid-July-late September), and post-berry seasons. Thirty-two of 35 (91%) illegally killed grizzly bears and 20 of 24 (83%) bears killed in self-defence occurred during spring and fall hunting seasons. PW mortalities were spread throughout the year. However, 24 of 42 (57%) and 32 of 42 (76%) bears killed by management actions (PW) took place during the berry season and peak tourist season (June through September) respectively. Both highway mortalities occurred during the berry season.

Figure 4. Elevations of grizzly bear kill locations in the Alberta study area of the Central Rockies Ecosystem, 1972–2002 (n=180).
There were 397 records of known human-caused grizzly bear mortalities and three deaths of unknown cause on BC provincial lands from 1976–2002 (Table 4). There were no translocation records available. The average annual number of human-caused mortalities for the 27 year period, 1976–2002 was 14.7 bears/year with the highest number of deaths occurring from 1988–90 (61 mortalities; 20.3/year) and 1994–96 (86 mortalities; 28.7/year; Figure 5). There were only 2 grizzly bear deaths recorded in 1976, possibly due to poor reporting or recording of grizzly bear mortalities during this first year of record keeping. The one mortality in 2001 reflects the implementation of a one-year moratorium on grizzly bear hunting.


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<td>175</td>
<td>320</td>
<td>86</td>
<td>77</td>
<td>81</td>
</tr>
<tr>
<td>PW</td>
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<td>48</td>
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<tr>
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<td>229</td>
<td>400</td>
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</table>

* LH legal harvest, PW management kill, IL illegal kill

Legally killed grizzly bears (LH) accounted for 81% (n=320) of all known human-caused mortalities followed by management kills/removals (PW 16%) and illegally killed bears (IL 4%). There was insufficient detail in the BC mortality database to examine the contributing factors that led to non-hunting grizzly bear mortalities.
Sex and Age Analysis

Records showed the sex, age and cohort of 396, 329 and 327 grizzly bears that died (all causes) (Table 5). The overall male:female ratio of dead bears was 65:35. Adult males accounted for 37% of bears killed followed by subadult males (28%), adult females (16%) and subadult females (15%). Seventy-three records had either no sex or age data.

Thirty-one percent of the LH (n=319) and other hunting-related (IL, n=15) mortalities were independent female bears. Females accounted for 65% of management kills throughout the entire period of analysis (9/15, 1976–89; 31/47, 1990–2002).

Table 5. Numbers and percentages of human-caused grizzly bear mortalities by sex, age and cohort in the BC study area of the Central Rockies Ecosystem, 1976–2002.

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</tbody>
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British Columbia Spatial and Temporal Analyses

Ninety percent (9872 km²) of the BC study area was in suitable grizzly bear foraging and denning habitat as classified by the elevation cut off. Zones of influence occupied 37% of the BC study area and 42% of the area of suitable grizzly bear habitat. Mortalities were not randomly distributed on the landscape. Fifty-six percent (208 of 369 with accurate locations) of human-caused grizzly bear deaths occurred within buffers along roads and trails compared to 34% of the sample of random points. This clumping of mortalities within the zones of influence was significant (G=49.791, df=1, P=1.719 x 10⁻¹²). Fifty-three percent and 4% of mortalities occurred along roads and trails respectively.

Of 161 bears killed outside of ZOIs, 152 were hunting related (149 LH, 3 IL) and 9 were management kills/removals. Area-concentrated kills occurred at Elkford, Windermere, upper Elk Valley, Blaeberry River, Luxor Creek, Palliser River, Moose Creek, upper Albert River, White River, Blackwater Creek and Bush Arm (Figure 6).

Since 1989, the average annual mortality increased to 17.6 deaths/year (n=171) from 12.2 deaths/year (n=229) during the early analysis period. This was the result of an increase in both LH (10.3 –13.5 deaths/year) and PW (1.1 – 3.7 deaths/year) mortalities during 1990–2002. Deaths of independent female
bears (all human causes) increased slightly as a percentage of total mortality (30% to 31%) although the annual number of female mortalities increased from 2.9/year during the 1976–89 period to 4.5/year in the 1990–2002 period.

The female percentage of legally harvested bears was 30% through both analysis periods.

Elevational Analysis

In the BC study area, 369 mortality locations ranged from 700–2900 m (2280–9450 ft) (Figure 7) and 87% occurred below 2100 m (6850 ft). Treeline averages about 2250–2360 m (7330–7700 ft) along the western slopes of the Rocky Mountains.

Seasonal Analysis

Of 77 dated non-sport grizzly bear mortalities, 19 (25%), 45 (58%), and 13 (17%) took place in the pre-berry, berry (mid-July-late September), and post-berry seasons. All 14 illegally killed grizzly bears died during spring and fall hunting seasons. PW mortalities were spread throughout the year. However, 43 of 63 (68%) and 45 of 63 (71%) management kills/removals took place during the berry season and peak tourist season respectively.
Figure 6. Grizzly bear mortality locations in the BC study area of the Central Rockies Ecosystem, 1976–2002.
Figure 7. Elevations of grizzly bear kill locations in the BC study area of the Central Rockies Ecosystem, 1976–2002 (n=369).

**DISCUSSION**

Human-caused mortality has been the predominant way that grizzlies have died in the CRE, including jurisdictions with grizzly bear and ungulate hunting (portions of Alberta and BC), with ungulate hunting but no grizzly bear hunting (portions of Alberta and BC) and without any hunting (Banff and Yoho National Parks, Benn and Herrero 2002). The 229 recorded human-caused grizzly bear deaths in the Alberta study area and 397 in the BC portion of the CRE were considered to be the minimum number from 1972/1976–2002. As the potential number of unreported kills is difficult to accurately estimate, they were not factored into these analyses. McLellan et al. (1999) noted that management agencies would have only detected between 45 and 51 percent of the human-caused mortalities of a radio-collared bear sample. The Alberta Fish and Wildlife Division added 25% of the total reported mortality to compensate for unreported kills. In their assessment of Alberta harvest allocation, Stenhouse et al. (2003) recommended adding 10-15% for wounding losses and setting the unreported mortality rate at 100% of the non-harvest mortality. The BC Ministry of Wildlife, Lands and Parks uses 2% of the population estimate for unreported mortality in grizzly bear population units (GBPUs) where bear-human conflicts are common and 1% in other GBPUs (Peek et al. 2003). They note the potential for a high female portion of this unreported mortality, based on a reported 42% of the unreported kill of a sample of radio-collared bears being female (McLellan et al. 1999). Banci (1991) estimated unreported mortality at between 25-100% of the total known kill in BC.

**Alberta**

The number of grizzly bears killed in the Alberta study area declined slightly between the 2 periods of analysis. This was mostly attributable to the implementation of limited entry hunting, which resulted in a 32% drop in legally harvested grizzly bears. In contrast, the mortality types related to the presence of food and garbage attractants increased substantially on provincial lands with and without grizzly bear hunting, even with greatly improved food and garbage management, informative science-based public education regarding bear-human conflict and more protective management policies.

The growing population base of Calgary, Canmore and other rural Alberta communities has led to increased development (industrial, recreational and rural residential) pressures and the increased killing of grizzly bears that become attracted to developments and people’s activities, especially when there is the
opportunity for a food reward for the bear. Relative to GBMAs in most other regions of the province (Stenhouse et al. 2003), with the exception of 1988, grizzly bear mortality for Grizzly Bear Management Areas (GBMAs) in the Alberta portion of the CRE from 1988 to 2002 was low south of the Bow River (no hunting) to moderate north of the Bow River (hunting permitted). Garshelis et al. (2005) calculated vital rates for grizzly bears trapped in the Bow River watershed portion of the CRE, 1994–2002. Even with the low reproductive capacity of this local population, and the high proportion of females killed in Banff National Park (Benn and Herrero 2002), the 95% survival rate (5% mortality rate) for adult female grizzly bears indicated a probable positive growth rate. However, during 2003–2004 the best available data showed significantly decreased survival rates, 88% for 2003, and 71% for 2004, suggesting population decline during these more recent periods (Chapter 5.2, this report).

Sex and Age Analysis

The composition of females in the harvest and total mortality was within the recommended 35% of the kill over the entire 1972–2002 period. However, this was extremely variable from year to year and area to area. Although detecting trends from analysis of age and sex structure in the kill is controversial (Harris and Metzgar 1987), analyses by Stenhouse et al. (2003) suggested a declining trend in the age of females in the total mortality in BMA 4C (north of the Bow River in the CRE).

Stenhouse et al. (2003) also noted that more females than males were killed in GBMA 5 (Kananaskis Country) during the 1997–2002 period. As non-harvest mortality types are non-selective for sex, female mortality may exceed sustainable levels during some years and cumulatively present a risk to the population. A series of years, such as apparently occurred in the Bow River Watershed during 2003–2004, with high female mortality could affect the tenuous positive growth rate (Garshelis et al. 2005) for many years. Adult females may preferentially use habitats near people, presumably to avoid adult males (Mattson et al. 1992). Thus, they are prone to habituation to humans and attraction to human food and garbage, increasing their mortality risk relative to males in these contexts and their potential for being destroyed or relocated as “problem” animals (Mattson et al. 1987). Craighead et al. (1995) described this dynamic in the Yellowstone Ecosystem.

Spatial and Temporal Analyses

Legally hunted grizzly bears accounted for the highest number of mortalities north of the Bow River. Kills related to hunting by Treaty Indians and ungulate hunters dominated south of the Bow River, followed closely by management kills/removals that increased substantially after 1987.

The results of interviews with Alberta grizzly bear hunters and wildlife managers in Alberta with respect to where bears were killed, and subsequent analysis of data thus generated, revealed that most grizzlies died close to human access. Spatial analyses showed a clumping of mortalities along roads and trails, and high concentrations of kills along certain drainages. North of the Bow River, where grizzly bear hunting is permitted, most mortalities occurred along trails, remote from motorized roads. This pattern was also observed in other jurisdictions of the CRE (Chapter 5, this report), and in other populations (Mattson et al. 1987, Mace et al. 1996, McLellan and Shackleton 1988a). Roads and trails improve access for hunters and poachers (McLellan and Shackleton 1988a), and increase the potential for negative bear-human encounters (McLellan and Shackleton 1988b). Thomas et al. (1976) determined that the number of hunters reaching hunting blocks decreased with distance from trails, roads and camping sites.

A small sample of mortalities showed that adult and subadult males were the main cohorts killed outside of the ZOIs. Adult males often dominate the backcountry habitats, farthest from human activities (Mattson et al. 1987). Subadult males may be more available in the backcountry during the spring hunt, as they may disperse widely in search of vacant home ranges (Bunnell and Tait 1985, McLellan and Shackleton 1988b).

Resource selection function analyses of ESGBP mortality data for the Alberta portion of the CRE by Nielsen et al. (2004) showed that subadult males were killed both remote from and close to access features. They suggested that during the spring hunting season, grizzly bears were further from access or hunters accessed more remote areas. However, they did not include seismic lines and modeled at a scale (30 m resolution) that probably failed to identify many horse and quad accessible trails (Scott Nielsen, Department of Biology, University of Alberta, Edmonton, Alberta, personal communication). Also, bears frequent valley
bottom areas during the spring due to snow cover at higher elevations. In this regard, Nielsen et al. (2004) found a positive correlation between mortalities and proximity to water. In this part of Alberta most drainages are accessible by some form of road or trail.

**Elevational Analysis**

We found that grizzly bears died at relatively low elevation near human developments, and in areas with easy access. All mortalities occurred below the alpine ecological zone. 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 and Herrero (1998b) showed that human use and developments caused a reduction in the amount of secure habitat for grizzly bears, and as previously mentioned, roads and trails increase the potential for bear-human encounters (McLellan and Shackleton 1988a). 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).

Mortalities at the lowest elevations in the Alberta study area coincide with ranching and agricultural land uses outside of the forest reserves and in the lower reaches of valleys on crown land. The main causes of grizzly bear death in these areas are the result of management control and illegal activities.

**Seasonal Analysis**

We found that a high proportion of mortalities occurred during the berry season. Mid-July to early October is the time when grizzlies in the Central Rockies Ecosystem feed primarily on buffaloberry (*Shepherdia canadensis*) at lower and mid elevations, often along roads and in close proximity to people.

**British Columbia**

Legal harvests accounted for a large majority of mortalities in the database. Limited entry hunting was introduced in 1982 as a way to regulate the distribution of hunters across the landscape and prevent area-concentrated kills, however area concentrated kills remain a concern (Chapter 6.6, this report). Population studies in the Flathead River and Revelstoke areas showed larger population sizes than previously thought, and with positive growth rates (Bruce McLellan, BCMOELP Forest Service Research Branch; Guy Woods, BCMOELP Senior Wildlife Biologist; personal communication). Thus, more permits were allocated (50% increase in 1989; Simpson et al. 1995) to maximize the harvest within the target of 4% of the population estimate.

The number of grizzly bears killed in the BC study area increased between the 2 periods of analysis, primarily because of the large number of LH mortalities. Management kills also increased in the 1990–2002 period, even with improved food and garbage management. A spike in PW mortalities occurred in 1994–95 was probably the result of the 1994 closure of several landfills in southeast British Columbia. Bears losing such a food source, often seek food around other human developments and settlements (Mattson et al. 1992, Craighead et al. 1995, Bennett 1996). The number of grizzly bears removed from the ecosystem due to management control was likely higher by some unknown number of translocations than are recorded here. Teske (1994 in Simpson et al. 1995) noted that in the Kootenay region of BC of which our study area is a part, wildlife control led to “larger than normal numbers of relocations of grizzly bears”.

The high percentage of mortalities occurring in road buffers reflects the large amount of backcountry roading in BC. These roads are predominantly forestry and mining roads.

**Sex and Age Analysis**

The female portion of the harvest and overall mortality remained around the recommended 30% of the kill over the entire 1972–2002 period. However, management kills claimed a high proportion of females throughout the entire period of analysis. This pattern was also seen in Alberta and the adjacent national parks (Benn and Herrero 2002). As previously described, females may use habitats near people, increasing their
risk of habituation to humans and thereby their risk of being killed in management actions (Mattson et al. 1987).

**Elevational Analysis**

The majority of mortalities occurred below treeline. Although we believe the same relationship exists as in Alberta, elevations in the BC study area are less accurate than in the other jurisdictions due to the coarse resolution of mortality locations (+1000 m).

**Seasonal Analysis**

We found that a high proportion of mortalities occurred during the berry season. As in Alberta, Mid-July to early October is the time when grizzlies in the BC portion of the Central Rockies Ecosystem feed primarily on berries. In BC there are diverse berry feeding opportunities. In addition to buffaloberry (*Shepherdia canadensis*), berries in particular of the genus *Vaccinium* occur at lower and mid elevations, often along roads and in close proximity to people.

**CONCLUSIONS AND RECOMMENDATIONS**

Hunting, human intolerance, inadequate management of access and food attractants, and ongoing recreational and industrial development continue to be important contributing factors to grizzly bear mortality in the Alberta and BC portions of the Central Rockies Ecosystem. Significant steps have been taken by managers in all jurisdictions to reduce human-caused grizzly bear mortality. However, bear hunting, which occurs in a large portion of the CRE, is based on crude population estimates usually without confidence intervals. This combined with the mortality risk associated with human food and garbage attractants and extensive roading presents a risky dynamic for the sustainability of the CRE grizzly bear population. By considering the following recommendations, aimed at reducing potential conflicts between humans and grizzlies, human-caused grizzly bear mortality and the potential for human injury can be reduced.

The results of the above analyses and those from previously published research on mortality in grizzly bear populations throughout North America, allowed us to reach the following general conclusions, and to make recommendations with respect to managing grizzly bear mortality in the Central Rockies Ecosystem. These conclusions and recommendations are based on the following three assumptions:

- the databases represent the minimum number of grizzly bear kills/removals;
- the stated goal of management agencies in Alberta and BC is to maintain or enhance the current population size and distribution of grizzly bears; and
- the recreational hunting of grizzly bears is an acceptable practice provided it is scientifically demonstrated to not cause population decline.

**Conclusion 1:** A high proportion of all grizzly bear deaths throughout all jurisdictions in the CRE were the result of human actions. Managing grizzly bear mortality entails managing human activities in grizzly bear habitat. We conclude that land use that considers the needs of grizzly bears requires interagency planning and management at a regional scale. This includes:

1. all jurisdictions developing the same reporting methods and conventions for recording accurate and complete mortality and relocation data;
2. dedicating funds to ensure that staff have the ability to collect data (e.g. aging from teeth) in a timely fashion (in the past age and sex information have been inconsistently recorded);
3. recording accurate (UTM) locations in order to conduct future spatial analyses (in Alberta information has been recorded at the scale of a section of a township and in BC to ± 1000m);
4. increasing funding for research and application regarding aversive conditioning techniques;
5. continuing to use more hard (aversive conditioning) on-site releases or within home range relocations;
6. making the practice of closing public areas during periods that bears (especially females and family groups) are known to use them more widespread; and
7. continuing to improve educational programs regarding living and recreating safely in bear country.
Conclusion 2: This analysis was based on the recorded (minimum) number of mortalities/relocations. Unreported mortality has been calculated at 46–51% and up to 100% of known mortality (McLellan et al. 1999). We recommend:

1. increasing the 25% adjustment figure for unreported mortality in Alberta by adding in a factor for wounding losses of 10-15% of legally killed bears and 100% of non-harvest mortalities (McLellan et al. 1999, Stenhouse et al. 2003); and
2. committing to increasing levels of enforcement in areas with a history of vandalistic and illegal grizzly bear killing.

Conclusion 3: Within the BC portion of the CRE where hunting is permitted, harvest and total mortality appear to have been within acceptable parameters (Peek et al. 2003). In Alberta it is less clear whether sustainable hunting mortality has been attained (declining trend in age of females in total mortality, Stenhouse et al. 2003). These conclusions are, however, contingent on the population estimates used. Self-defense, illegal, and mistaken identity kills by ungulate and black bear hunters account for a large percentage of grizzly bear deaths in some regions of the CRE. We recommend:

1. increasing the level of commitment to developing and using science-based population assessment techniques with confidence intervals;
2. continuing to closely monitor harvest and total mortality, and adjust hunting permit allocations accordingly;
3. where hunting (bear and ungulate) is permitted, creating No Shooting Zones around high human use areas, and along high use roads to reduce the killing of habituated grizzlies by hunters and other people with guns who encounter these bears at close range; and
4. requiring hunters going into grizzly bear habitat to show a proficient understanding of bear identification, behavior, and safety.

Conclusion 4: Most management control mortalities occur where bears are attracted to human food and garbage, livestock and feed, and this has been associated with a high proportion of females in the kill. We recommend that effective legislation and enforcement be enacted to ensure that:

1. all concessionaires in the parks and provinces secure all food attractants and that this is regularly inspected;
2. all remaining public and commercial landfills and other garbage storage and transfer facilities are bear proofed with appropriate safeguards, preferably electric and chain link fencing;
3. all back country users (campers and hunters) be required to secure food attractants including feed for stock and carcasses;
4. agency personnel continue to assist landowners in reducing livestock-bear conflicts; and
5. the predator compensation program be improved. Fair compensation for loss to landowners exercising good husbandry techniques will instill tolerance for bears on their land.

Conclusion 5: Spatial analyses clearly showed that most grizzlies died within a narrow zone along roads and trails, and around human settlements. Yet, roads and major developments continue to be constructed in grizzly bear habitat and remain open to the public. We recommend:

1. collecting more detailed access-related (type of access route and method of travel, distance of kill from nearest access, presence of human and natural food attractants near the access route) and location information (UTM coordinate) with each grizzly bear mortality;
2. regulating access into high quality grizzly bear habitat through quotas and/or road closures, particularly in areas with past concentrations of mortality; and
3. committing to no new roads into the remaining secure grizzly bear habitats, and requiring the decommissioning of industrial roads at project termination.
Conclusion 6: Temporal analyses of the mortality data, as conducted in this project, are snapshots in time. We recommend:

1. repeating temporal analyses every five years, or when updated population estimates are available, to assess changing management strategies, and other events that affect grizzly bear survival.

The CRE will face increasing pressure from human activities as nearby urban and rural populations grow (Chapter 13, this report). As the CRE grizzly bear population exists at a low population density and has a low reproductive potential, it is vulnerable to increased mortality risk with the greater exposure to people. Thus, there will be an ongoing need to fund scientific research into accurately estimating population size and better understanding the effects of human presence and access into grizzly bear habitat. Finally, until accurate population estimates are available, we recommend a conservative approach by reducing overall human-caused grizzly bear mortality. This approach would be enhanced by integrating the above recommendations into regional planning and management policy.

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6.5 MODELLING THE SPATIAL DISTRIBUTION OF HUMAN-CAUSED GRIZZLY BEAR MORTALITIES IN THE CENTRAL ROCKIES ECOSYSTEM OF CANADA

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ABSTRACT
We examined the spatial patterns of 297 human-caused grizzly bear mortalities from 1971 to 2002 within the Central Rockies Ecosystem (CRE) of Canada to explore relationships between mortalities and variables reflecting human development, terrain, and vegetation. Using logistic regression, we modelled the distribution of grizzly bear mortalities based on local landscape attributes as well as examining variation among demographic status, seasons, and mortality type. Grizzly bear mortalities were concentrated in 3 main regions of the CRE: (1) Lake Louise; (2) Banff town site; and (3) Alberta Provincial lands near the Red Deer River. We found no evidence for environmental differences in mortality locations between sexes or season, while sub-adult male and legal harvest mortalities were more dispersed than other mortalities. Models describing the relative risk of mortality were positively associated with human access, water, and edge features, while negatively associated with terrain ruggedness and greenness indices. Model predictions fit well with independent data. Overall, relatively little of the landscape was secure from human-caused mortality for grizzly bears. This would be most directly remedied by controlling access.

This is a slightly abridged version of a paper published in Biological Conservation, 2004, 120: 101–113. The methods section has been shortened.

INTRODUCTION
Large carnivores are particularly vulnerable to extinction because of their low density, high trophic level, and low reproductive rates (Russell et al., 1998; Purvis et al., 2000a; 2000b). Anglo-European settlement of previously ‘unoccupied’ lands together with increasing human density have been well correlated with historic carnivore extirpations (Woodroffe, 2000; Mattson and Merrill, 2002). Currently, however, effective land-management policies can be important determinants of population persistence (Channell and Lomolino, 2000; Linnell et al., 2001; Homewood et al., 2001). For North American grizzly bears, Ursus arctos, populations and distributions have been substantially reduced in the past century (Mattson and Merrill, 2002). Much of this loss has occurred in the contiguous United States and southern Canada (McLellan, 1998) and can be explained by historic conflicts between humans and bears reflecting pioneering attitudes and corresponding to two of Diamond’s (1989) evil quartets of extinction: overkill and habitat destruction/fragmentation.

Much research on grizzly bear conservation has focused on habitat selection and the spatial distribution of grizzly bear habitats using radiotelemetry data (e.g., Mace et al., 1996; 1999; Waller and Mace, 1997; Nielsen et al., 2002). Common factors used to describe bear occurrence include landcover or vegetation type (Mace et al., 1996; McLellan and Hovey, 2001), distance to streams and forest edge (Nielsen et al., 2002; Theberge 2002) vegetation indices from satellite data, such as greenness (Mace et al., 1999; Stevens, 2002), and terrain ruggedness (Theberge, 2002; Naves et al., 2003). Although substantial information on the spatial occurrence of bears exists, relatively little has been done to examine how spatial factors, especially human-related features, influence human-caused grizzly bear mortality in local populations (see however, Johnson et al., 2005; Mattson and Merrill, 2004). It is well accepted that survival, particularly of adult females, is the most important factor shaping population growth and long-term viability of grizzly bear populations (Wiegand et al., 1998; Pease and Mattson, 1999; Boyce et al., 2001; McLoughlin et al., 2003). Given the threatened status and/or nature of many remaining grizzly bear populations, including those in the Central Rockies Ecosystem (McLellan, 1998), the identification of mortality sinks (Knight et al., 1988) is crucial to the future conservation of grizzly bears. Mortality risk maps may be useful for describing habitat-based
population viability (Boyle, 2002) or the identification of bear habitats and core areas with high conservation value based on multidimensional habitat models of survival and reproduction (Naves et al., 2003). Although methods are well developed for survival modelling (Cox and Oakes, 1984), most areas of current grizzly bear range lack the required information on individual exposure and death. Alternative approaches that make use of ad hoc government mortality records are required. Development of regional spatial mortality risk models for grizzly bears would be an important contribution to conservation.

Grizzly bear populations within Canada, although not as reduced as within the contiguous United States, still face substantial pressures from habitat degradation and reduced population growth rates caused from excessive mortality (McLoughlin et al., 2003). Currently, only 37% of the 3.5-million-km² grizzly bear range is considered secure, with the remaining 63% considered vulnerable (Banci et al., 1994). Risks associated with these vulnerable populations are the expansion and development of resource extraction activities, including oil and gas exploration and development, timber harvesting, and mining. Previous research on human-caused grizzly bear mortality has shown a strong relationship between bear mortalities and roads (McLellan, 1989). As resource extraction activities enter an area, initially without much access, road construction provides entry for hunters, poachers, and settlers, the major cause of grizzly bear mortality (McLellan, 1989). Even in ‘pristine’ landscapes such as national parks where grizzly bears are protected from hunting, as much as 100% of known adult grizzly bear mortalities occurred within 500 m of roads or 200 m of high use trails (Benn and Herrero, 2002). Likewise, examinations of survival and mortality in the Greater Yellowstone Ecosystem revealed the highest risk of mortality for grizzly bears in areas of high road density and for those animals experiencing repeated management actions (Boyle et al., 2001; Johnson et al., 2005). Most often, researchers have focused on habitat selection and assumed that the identification of areas most frequently occupied by animals represent high quality habitats or contribute to fitness (Garshelis, 2000). In certain circumstances, however, areas frequented by animals and therefore identified as ‘high’ quality habitat within habitat models, can be considered attractive sinks where risk of mortality is high (Delibes et al., 2001; Naves et al., 2003). Identifying attractive sinks as high quality habitat would be misleading for management and conservation action. Research that identifies mortality sinks, or the opposite secure high-quality sites, as it relates to human features, terrain, and vegetation, is important if our goal is to maintain viable future populations of grizzly bears.

In this paper, we develop predictive models and maps that describe the distribution of human-caused grizzly bear mortalities for the Alberta and Yoho National Park portions of the Central Rockies Ecosystem of southern Canada. Our goal was to understand, through modelling, the relationships among bear mortality locations and landscape-level physiographic and human variables. More specifically, we were interested in: (1) examining the spatial density of grizzly bear mortalities; (2) evaluating possible differences in the physiographic attributes of mortality locations relative to demographic status, season, and mortality type; and (3) developing predictive models that estimate the relative probabilities of bear mortality (risk) given multi-variable combinations of physiographic variables. Our working hypothesis is that grizzly bear mortalities are related to factors describing human accessible habitats in those locations where bears are likely to frequent. Mattson et al. (1996a; 1996b) conceptualises this as the frequency of contact between bears and humans. At increasingly larger spatial and temporal scales, however, the lethality of contact can differ based on jurisdictional boundaries and temporal changes in management regime (Mattson et al., 1996a; 1996b; Mattson and Merrill 2002). We attempt to examine spatial expressions of these concepts in the Central Rockies Ecosystem of Canada using empirical modelling of grizzly bear mortality locations, animal use locations, and geographic information system (GIS) data typical of most grizzly bear habitat models.

STUDY AREA

This study encompassed a 29,264-km² area of the Central Rockies Ecosystem (CRE) in southern Alberta and a small portion of adjacent British Columbia, Canada (Figure 1). This study area encompasses a portion of the known distribution of grizzly bears in western Canada. This area included Banff and Yoho National Parks and an Alberta Provincial area south of Banff referred to as Kananaskis Country. The area was bordered to the west by the Continental Divide and Yoho National Park, being no further than 117.0°W longitude. The northern boundary was primarily along Highway 11 and occurred south of 52.5°N latitude. The southern border was at latitude 50.0°N, while the east border was irregular in shape, but no further east.
than 114.0°W longitude. Legal harvest of grizzly bears, through a limited entry spring hunt since 1988, occurred in the areas outside of Banff and Yoho National Parks and Kananaskis Country (Figure 1). Mountainous terrain dominated the study area with elevations varying from 839 m along the North Saskatchewan River at Rocky Mountain House to 3,588 m along the Continental Divide. Given a strong gradient in elevation, a diverse array of local ecosystems and plant communities existed, but most generally could be divided into the following 5 ecoregions: (1) alpine; (2) sub-alpine; (3) upper boreal-cordilleran; (4) aspen parkland; and (5) montane.

Figure 1. Study area map depicting elevation, study area boundary, Province border, places, and general location within Alberta and British Columbia, Canada (small inset map in lower left corner).
METHODS

Mortality location data

We collected grizzly bear mortality information across the CRE for a 32-year period from 1971 to 2002. Mortalities were defined as both dead bears and those bears translocated a sufficient distance to be considered eliminated from the population. For each mortality record, the location (UTM coordinates), accuracy of location, month, year, sex, age, and cause of mortality were obtained from National Park and Provincial management records (Benn, 1998; Benn and Herrero, 2002). However, because locations of mortalities in Alberta were provided at the scale of the township, and some mortalities in the National Parks were imprecise or missing, persons involved with the mortality event were interviewed to associate specific coordinates on a map and locations were then digitised into a GIS. For spatial mortality models, we used 279 accurate and reasonably accurate locations that were associated with human-caused events. Bear mortalities from human causes were classified into 2 classes: (1) legal harvest; and (2) non-harvest/other (self-defense, First Nation, accidents, railroads, highway, problem wildlife, research, and translocation).

GIS (spatial) predictor variables

We generated 7 geographical information system (GIS) layers that were related to land cover, terrain, and humans. Land cover was estimated from Landsat TM satellite imagery dated from 1995 to 1998 and occurring at a 30-m pixel resolution. Land cover was initially classified into 9 classes: conifer forest, deciduous forest, shrub, avalanche, grass, cropland, ice/snow, rock/bare soil, and water (Wierzchowski, 2000). This map was further simplified by reclassifying the image into 5 more general land cover categories. These reclassified categories were conifer forest, deciduous forest, shrub (shrub and avalanche), grassland (grass and cropland), and non-vegetated areas (ice/snow, rock/bare soil, and water). From the classified land cover imagery, we further derived a grid (30-m pixel) representing the distance (km) to edge of any nearest land cover.

Using the same satellite imagery, we derived a greenness index based on a tasselled-cap transformation of the Landsat TM bands (Crist and Ciceron, 1984), which has been found to relate to leaf area index (LAI) and vegetation productivity (White et al., 1997; Waring and Running, 1998). Greenness has previously proven useful for identifying grizzly bear use in mountainous regions (Manley et al., 1992; Mace et al., 1996; 1999; Gibeau et al., 2002; Nielsen et al., 2002; Stevens, 2002), and as such has been recognized as a surrogate of grizzly bear habitat quality (Stevens, 2002). Using hydrographic GIS data, we also derived a 30-m grid that represented the distance (km) to any nearest water feature (water body, permanent stream, intermittent stream, indefinite stream). As a final distance metric, we calculated, again in a 30-m grid, the distance (km) to nearest linear human use feature (motorized or non-motorized), but did not include exploratory seismic lines that are common to areas outside of the Parks. To characterize terrain, we generated a terrain ruggedness index (TRI) within 300-m circular moving windows, as previous examinations have found this scale to be an important predictor of bear occurrence (Theberge, 2002).

DATA ANALYSIS

Spatial densities of grizzly bear mortalities

To qualitatively examine spatial patterns and concentrations of grizzly bear mortalities, we used 3 separately scaled moving windows to calculate the total density of mortality locations in a GIS. These moving window analyses corresponded to a scale of, (1) 520-km² (12,869-m radius) or the estimated average multi-annual 95% fixed kernel home range for female grizzly bears in the CRE (Stevens, 2002); (2) 900-km² (16,929-m radius) or the approximated lifetime home range of a female grizzly bear in Yellowstone (Blanchard & Knight, 1991); and (3) 1,405-km² (21,153-m radius) or the estimated average multi-annual 95% fixed kernel home range for male grizzly bears in the CRE (Stevens, 2002). All human-caused mortalities over the past 32 years were summed within moving windows and applied to 100-m pixels (1-ha grid) in a GIS map. All pixels with a mortality density of 0 were qualitatively considered secure sites, while those exceeding 31 mortalities (≥ 1 mortality/yr) were qualitatively considered high mortality zones.
Mortality differences among demographic status, season, and mortality type

We used logistic regression to assess relationships between landscape attributes of mortality locations (GIS predictor variables) and the categories of demographic status, season, and mortality type (response variables). Sex was contrasted for either female (1) or male (0) observations, while for sex-age class composition, we tested for sub-adult (3-5-yr-old) male mortalities (1) versus all the other (0) mortalities (e.g., young, adult, and sub-adult females). To examine whether seasonal differences were present, we compared mortalities that occurred during the berry season (1) with those mortalities that occurred outside of the berry season (0). We defined the berry season to be the period from 1 August to 31 October. During this time, grizzly bears in the region forage on Canada buffaloberry *Shepherdia canadensis* and numerous species of blueberry and huckleberry *Vaccinium* spp. (Hamer and Herrero, 1987; Hamer et al., 1991; Nielsen et al., 2003). Finally, we examined whether environmental differences existed in mortalities associated with legal harvest locations (1) compared to other human-caused mortalities (0) outside of protected areas.

Random versus mortality locations- mortality distribution models

To characterize the landscape within the defined study area, we generated a sample of random (2-dimensional uniform distribution) locations with a sampling intensity of 1 point per 5-km$^2$ ($n = 5,852$). These random landscape locations (0) were contrasted with human-caused, mortality locations (1) using an availability-presence design with the following log-linear form:

$$w(x) = \exp (\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k),$$

where $w(x)$ represents the relative mortality distribution function (low to high mortality rank) and $\beta$ the mortality coefficient estimated from environmental predictors $x_i$ (Manly et al., 1993). Coefficients for the model were estimated using logistic regression. A global mortality distribution model representing all recorded mortalities was developed along with specific models for significant demographic status, season, and mortality type classes identified as significant in the previous section.

To validate our models, we partitioned mortality data prior to model building into a model-training (80%) and model-testing (20%) data set. Model-training data and random (psuedo-absences) locations were used to develop model coefficients, while model-testing data were used for within sample independent validation. Using the test data, we examined the predictive capacity of the model (validation) by comparing model predictions to the observed number of withheld mortalities (Boyce et al., 2002).

Radiotelemetry versus mortality locations- the mortality risk model

Because the previous comparison between random and mortality locations does not consider the conditional nature of the mortality process (i.e., bears can only be killed where they are present, not necessarily all [random] locations), we also used logistic regression to contrast the location of grizzly bear mortalities with sites used by grizzly bears. We determined grizzly bear use by collecting 3,089 VHF radiotelemetry locations from 60 sub-adult and adult (35 female: 25 male) grizzly bears between 1994 and 2001. Similar methods were used for developing a mortality risk model as those in the previous section with the distinction being that radiotelemetry (0), not random locations, were contrasted with mortality (1) locations. For this analysis, all mortalities located outside the 100% minimum convex polygon (MCP) home range of individual radio-collared grizzly bears were excluded. We interpreted coefficients from the mortality risk model to represent those areas where grizzly bears are likely to die given that they selected particular habitats and resources (a form of conditional probability not satisfied with a comparison of random locations). Finally, we compared the ranked predictions of mortality distribution model with the mortality risk model using a weighted Kappa ($\hat{K}_w$) statistic (Monserud and Leemans, 1992; Næsset, 1996). We consider Kappa values greater than 0.75 to indicate very good to excellent agreement (1.0 is perfect), while values between 0.4 and 0.75 indicate fair to good agreement, and finally values less than 0.4 to indicate poor agreement (Landis and Koch, 1977).
RESULTS

Spatial densities of grizzly bear mortalities

Regardless of the scale examined, grizzly bear mortalities were concentrated within 3 regions of the Alberta study area; (1) Lake Louise; (2) Banff town site; and (3) Alberta Provincial lands near the Red Deer River northwest of Calgary (Figure 2). For the 900- and 1405-km²-scales, mortality densities within moving windows exceeded 31 mortalities for the above 3 identified areas, equivalent to ≥1 mortality event/year and qualitatively considered a high mortality zone. At the 520-km²-scale, only Lake Louise stood out in having more than 31 mortality events, although a very small area west of Banff also showed high mortality. Total area occupied in a high mortality zones ranged from 1.4% at the 520-km²-scale to 13.2% for the 1,405-km²-scale (Table 1). In contrast, the total area considered secure from human-caused mortalities (no recorded mortality events) ranged from 7.2% for the 1,405-km²-scale to 23.9% for the 520-km²-scale (Table 1).

However, 22% to 32% of secure habitat was in areas of non-habitat (rock, snow, ice, water), and high mortality density sites (>31 mortality events) for the Central Rockies Ecosystem of Canada. Mortality density estimates were based on moving windows of three scales, the first relating to local female home range sizes (520-km²), the second Yellowstone lifetime home range sizes (900-km²), and third local male home range sizes (1,405-km²).

Table 1. Percent composition of qualitatively defined secure (0 recorded mortalities), secure but non-habitat (rock, snow, ice, water), and high mortality density sites (>31 mortality events) for the Central Rockies Ecosystem of Canada. Mortality density estimates were based on moving windows of three scales, the first relating to local female home range sizes (520-km²), the second Yellowstone lifetime home range sizes (900-km²), and third local male home range sizes (1,405-km²).

<table>
<thead>
<tr>
<th>Variable</th>
<th>520-km²</th>
<th>900-km²</th>
<th>1405-km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secure</td>
<td>23.9</td>
<td>13.9</td>
<td>7.2</td>
</tr>
<tr>
<td>Secure, non-habitat</td>
<td>21.8</td>
<td>23.2</td>
<td>32.0</td>
</tr>
<tr>
<td>High mortality density</td>
<td>1.4</td>
<td>3.8</td>
<td>13.2</td>
</tr>
</tbody>
</table>

Mortality differences among demographic status, season, and mortality type

The landscape features at mortality locations for male and female grizzly bears were not differentiated by logistic regression ($\chi^2 = 8.38, p = 0.497$, d.f. = 9) (Table 2). Conversely, we found strong differences between sub-adult males and other sex-ages. The sub-adult male model was significant overall ($\chi^2 = 27.77, p = 0.001$, d.f. = 9) with distance to access feature and edge variables significant. Generally, sub-adult male mortalities were further from edges than other sex-age classes (Table 2). In addition, sub-adult male mortalities were more likely to be further from human access features than adult, young, and sub-adult female mortalities.
Figure 2. Distribution and concentration (density of recorded mortalities) of grizzly bear mortalities within the study area at 2 scales relating to the multi-annual 95% fixed kernel home ranges for female (a. 520-km²) and male (b. 1,405-km²) grizzly bears. Note the differences between scales and the high concentration of mortalities near Banff and Lake Louise town sites as well as the east slopes northwest of Calgary. A third scale relating to the lifetime home range of a Yellowstone grizzly bear (900-km²) is not shown but is intermediate between the scales depicted.
We did not find any temporal effects associated with berry season (August 1 to October 31), as the overall model was non-significant ($\chi^2 = 12.04, p = 0.211, \text{d.f.} = 9$). Finally, comparisons of legal harvest with other human-caused mortalities showed strong spatial environmental differences for mortality locations with a significant overall model ($\chi^2 = 23.30, p = 0.006, \text{d.f.} = 9$) and significant variables for distance to habitat edge and access features. Legal harvest locations occurred further from edges and access features compared with other mortalities, interpreted to mean that hunters must go further from a road to harvest bears and in other contexts, such as problem bears, human-caused mortality occurs nearer to roads.

### Random versus mortality locations- mortality distribution models

Irrespective of differences in demographic status, season, and mortality type, the global mortality distribution model significantly ($\chi^2 = 144.91, p < 0.001, \text{d.f.} = 9$) described grizzly bear mortalities within the studied portion of the CRE. Mortalities were positively associated with access, water, and edge features (i.e., negative coefficients for distance to feature), while negatively associated with terrain ruggedness and greenness indices (Table 3). Only the shrub land cover class proved to be significantly different from that of conifer forests, having higher mortality ranks. Spatial model predictions for the global model showed strong patterns of high mortality along the eastern slopes of the Rockies and human accessible areas within the Parks (Figure 3). Using the independent withheld testing data (validation) we found our global mortality distribution model to be predictive overall with scaled bins of relative mortality ranks relating to the number of mortality locations falling within those bins ($D = 1.0, p<0.001$; Figure 4).

Models describing sub-adult male mortalities were significant ($\chi^2 = 93.19, p < 0.001, \text{d.f.} = 9$) showing an association with water, low greenness sites, less rugged terrain, and in shrub habitats (Table 3). In contrast, the distance variables for edge and access features, although negative (more likely to be near that feature), were not significant. For the other sex-age class, however, mortalities were strongly related to edges and access features, with a significant model overall ($\chi^2 = 79.43, p < 0.001, \text{d.f.} = 9$). Similar to sub-adult males, mortalities for the other sex-age class were in low greenness sites and in less rugged terrain. Not only were other sex-age class mortalities more likely to occur in shrub habitats, but also in grassland areas.

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Table 2. Estimated coefficients (Coeff.) for GIS environmental predictor variables used to estimate if any spatial mortality differences existed among specific demographic status, sex-age, season, or mortality class when compared with other mortalities (e.g., berry season compared with non-berry season). Conifer forest was used as the reference category (indicator contrast) for comparisons with other landcover classes.

<table>
<thead>
<tr>
<th>Landcover type</th>
<th>Female Coeff.</th>
<th>S.E.</th>
<th>p</th>
<th>Sub-adult male Coeff.</th>
<th>S.E.</th>
<th>p</th>
<th>Berry Season Coeff.</th>
<th>S.E.</th>
<th>p</th>
<th>Legal harvest Coeff.</th>
<th>S.E.</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deciduous forest</td>
<td>0.109</td>
<td>0.463</td>
<td>0.814</td>
<td>-0.906</td>
<td>0.628</td>
<td>0.149</td>
<td>-0.046</td>
<td>0.455</td>
<td>0.919</td>
<td>0.075</td>
<td>0.590</td>
<td>0.899</td>
</tr>
<tr>
<td>Grassland</td>
<td>-0.021</td>
<td>0.461</td>
<td>0.964</td>
<td>-0.096</td>
<td>0.561</td>
<td>0.864</td>
<td>0.358</td>
<td>0.470</td>
<td>0.446</td>
<td>-0.341</td>
<td>0.577</td>
<td>0.555</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>0.636</td>
<td>0.745</td>
<td>0.393</td>
<td></td>
<td></td>
<td></td>
<td>0.726</td>
<td>0.749</td>
<td>0.332</td>
<td>-0.846</td>
<td>1.118</td>
<td>0.449</td>
</tr>
<tr>
<td>Shrub</td>
<td>0.010</td>
<td>0.356</td>
<td>0.978</td>
<td>-0.338</td>
<td>0.428</td>
<td>0.430</td>
<td>0.355</td>
<td>0.375</td>
<td>0.344</td>
<td>0.302</td>
<td>0.467</td>
<td>0.518</td>
</tr>
<tr>
<td>Greenness</td>
<td>0.010</td>
<td>0.073</td>
<td>0.891</td>
<td>0.005</td>
<td>0.090</td>
<td>0.959</td>
<td>0.048</td>
<td>0.074</td>
<td>0.511</td>
<td>-0.170</td>
<td>0.088</td>
<td>0.052</td>
</tr>
<tr>
<td>Distance to edge</td>
<td>-4.580</td>
<td>5.424</td>
<td>0.398</td>
<td>11.700</td>
<td>5.620</td>
<td>0.037</td>
<td>-9.293</td>
<td>5.749</td>
<td>0.106</td>
<td>11.977</td>
<td>6.119</td>
<td>0.050</td>
</tr>
<tr>
<td>Distance to water</td>
<td>-0.266</td>
<td>0.673</td>
<td>0.693</td>
<td>-1.732</td>
<td>1.040</td>
<td>0.096</td>
<td>0.741</td>
<td>0.671</td>
<td>0.270</td>
<td>-0.841</td>
<td>0.946</td>
<td>0.374</td>
</tr>
<tr>
<td>Distance to access</td>
<td>-0.736</td>
<td>0.370</td>
<td>0.047</td>
<td>0.942</td>
<td>0.353</td>
<td>0.008</td>
<td>-0.520</td>
<td>0.355</td>
<td>0.143</td>
<td>0.780</td>
<td>0.359</td>
<td>0.030</td>
</tr>
<tr>
<td>Terrain variability</td>
<td>3.251</td>
<td>3.464</td>
<td>0.348</td>
<td>-5.222</td>
<td>4.520</td>
<td>0.248</td>
<td>0.785</td>
<td>3.457</td>
<td>0.820</td>
<td>3.532</td>
<td>4.100</td>
<td>0.389</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.317</td>
<td>0.750</td>
<td>0.672</td>
<td>-0.824</td>
<td>0.922</td>
<td>0.371</td>
<td>-0.952</td>
<td>0.773</td>
<td>0.218</td>
<td>0.641</td>
<td>0.947</td>
<td>0.498</td>
</tr>
</tbody>
</table>

*Estimated coefficient convergence failed due to perfect classification (no sub-adult male mortalities recorded in non-vegetated areas).
In comparison to other sex-age classes, sub-adult male mortalities tended to occur further from edges and access features, nearer to water, and in less rugged terrain.

Models describing legal harvest mortalities were significant overall ($\chi^2 = 48.11, p < 0.001, \text{d.f.} = 9$), showing a strong association with water and less rugged terrain. Hunters were apparently successful in focusing their attention to streamside habitats, where animals are typically concentrated during the spring hunting season. There were non-significant, but consistent negative (nearer to features as for previous groups) relationships for access, edges, and greenness. For land cover types, only the shrub category was significantly different from that of closed conifer stands (Table 3). Non-harvest mortalities, on the other hand, were not only more likely to occur in shrub habitats, but also in grasslands with a significant model overall ($\chi^2 = 57.07, p < 0.001, \text{d.f.} = 9$). Distance to edge and access also were important indicators of non-harvest mortalities. Both were strongly negative, suggesting that vegetation edges and human-accessible areas were more dangerous for non-harvested grizzly bears. Greenness, distance to water, and terrain variability were non significant, but were still negative, suggesting a weak association. In contrast to non-harvest mortalities, legal harvests mortalities tended to occur further from access and edge features, nearer to water, less likely in grasslands, and finally, in less rugged terrain.

**Radiotelemetry versus mortality locations— the mortality risk model**

The mortality risk model, describing radiotelemetry versus mortality locations using GIS predictor variables, was significant overall ($\chi^2 = 170.49, p < 0.001, \text{d.f.} = 9$). Mortality locations occurred in deciduous forest and shrub land cover classes more so than closed conifer stands (reference category). Also, grizzly bear mortalities were more likely to occur nearer to edge, access, and water variables (Table 4). Finally, grizzly bear mortalities were significantly related to areas of low greenness and minimal terrain ruggedness. Overall predictions of mortality classes and validations of withheld mortalities within these classes were similar for the mortality risk and mortality distribution models (Figure 4). Coefficient coverage between the random-versus-mortality and the radiotelemetry-versus-mortality models failed to reveal large differences, although stronger associations of mortality for less rugged terrain, near edges, and within the deciduous land cover class was evident for the mortality risk model (radiotelemetry versus mortality locations). Furthermore, a weighted Kappa statistic ($\hat{K}_w = 0.78$) suggests very good to excellent agreement in the spatial predictions of mortality sites by the mortality distribution and mortality risk maps. Using the independent withheld testing data (validation) we found our global mortality risk model to be predictive overall with scaled bins of mortality risk relating to the number of mortality locations falling within those bins ($D = 1.0, p < 0.001$; Figure 4). The similarities with our mortality distribution model (random versus mortality locations) suggest that the random versus mortality locations were not overly tied up in habitat selection, but instead related to those processes influencing human-caused grizzly bear mortality.
Table 3. Estimated coefficients (Coeff.) for models describing the relative probability of grizzly bear mortality within the Central Rockies Ecosystem of Canada by contrasting mortalities with random locations. Standard errors (S.E.) and inferences were based on a 499-sample bootstrap estimate. Conifer forest was used as the reference category (indicator contrast) for comparisons with other land cover classes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global model (all)</th>
<th>Sub-adult male</th>
<th>Other sex-age</th>
<th>Legal harvest</th>
<th>Non-harvest/Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>S.E.</td>
<td>p</td>
<td>Coeff.</td>
<td>S.E.</td>
</tr>
<tr>
<td><strong>Landcover type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>0.405</td>
<td>0.264</td>
<td>0.125</td>
<td>-0.098</td>
<td>0.539</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.212</td>
<td>0.233</td>
<td>0.363</td>
<td>0.108</td>
<td>0.416</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>-0.158</td>
<td>0.414</td>
<td>0.702</td>
<td>-0.629</td>
<td>3.108</td>
</tr>
<tr>
<td>Shrub</td>
<td>0.813</td>
<td>0.205</td>
<td>&lt;0.001</td>
<td>0.784</td>
<td>0.318</td>
</tr>
<tr>
<td>Greenness</td>
<td>-0.133</td>
<td>0.041</td>
<td>0.001</td>
<td>-0.144</td>
<td>0.076</td>
</tr>
<tr>
<td>Distance to edge</td>
<td>-7.792</td>
<td>2.27</td>
<td>0.001</td>
<td>-6.005</td>
<td>3.032</td>
</tr>
<tr>
<td>Distance to water</td>
<td>-2.274</td>
<td>0.549</td>
<td>&lt;0.001</td>
<td>-3.524</td>
<td>1.291</td>
</tr>
<tr>
<td>Distance to access</td>
<td>-1.63</td>
<td>0.474</td>
<td>0.001</td>
<td>-0.632</td>
<td>0.588</td>
</tr>
<tr>
<td>Terrain variability</td>
<td>-8.09</td>
<td>1.599</td>
<td>&lt;0.001</td>
<td>-10.598</td>
<td>2.533</td>
</tr>
</tbody>
</table>
Figure 3. The distribution of mortality risk ranks from very low to very high based on the global mortality distribution (random versus mortality locations) model in the Central Rockies Ecosystem of Canada.
Table 4. Comparison of the mortality distribution (random versus mortality locations) and mortality risk (radiotelemetry versus mortality locations) with bootstrapped standard errors and significance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mortality distribution model</th>
<th>Mortality risk model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>S.E.</td>
</tr>
<tr>
<td>Landcover type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>0.405</td>
<td>0.264</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.212</td>
<td>0.233</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>-0.158</td>
<td>0.413</td>
</tr>
<tr>
<td>Shrub</td>
<td>0.813</td>
<td>0.205</td>
</tr>
<tr>
<td>Greenness</td>
<td>-0.133</td>
<td>0.041</td>
</tr>
<tr>
<td>Distance to edge</td>
<td>-7.792</td>
<td>2.27</td>
</tr>
<tr>
<td>Distance to water</td>
<td>-2.274</td>
<td>0.549</td>
</tr>
<tr>
<td>Distance to access</td>
<td>-1.630</td>
<td>0.474</td>
</tr>
<tr>
<td>Terrain variability</td>
<td>-8.090</td>
<td>1.599</td>
</tr>
</tbody>
</table>

Figure 4. Percent composition of very low to very high mortality risk pixels in the Central Rockies Ecosystem of Canada based on the mortality distribution (random-based map) and the mortality risk (radiotelemetry-based map) models (a.). Area-adjusted frequency of withheld (testing data) mortality validations (n = 45) falling within very low- to very high- mortality risk bins (b.). Although only a small fraction of mortality pixels are in high- and very high bins (a.), the majority of mortalities (per area) are occurring in these sites (b.).
DISCUSSION

Grizzly bear mortalities were concentrated in three regions of the study area: (1) Lake Louise; (2) Banff town site; and (3) Alberta Provincial lands near the Red Deer River (Benn, 1998). Unlike Lake Louise and Banff, a large proportion of human-caused mortalities in the Red Deer River basin were caused by legal spring harvests. For 2 scales (900-km² and 1,405-km²), the number of mortalities within home-range-sized moving windows exceeded or equalled the number of years examined (≥ 1 mortality/year) for these 3 regions suggesting very high mortality rates. Temporal variation in mortalities over the past 3 decades have, however, been evident for different regions, with some areas like the Banff town site exhibiting reduced rates of mortality in the past number of years (Benn, 1998; Benn and Herrero, 2002). Secure areas varied from 7.2% to 23.9%, although large proportions of these areas were considered to be non-habitat.

Comparisons of demographic status, season, and mortality type revealed spatial discriminations in mortalities for sub-adult male/non-sub-adult male and legal hunting/non-legal hunting locations, while sex and season differences were similar. We found no spatial differences in mortality for season (berry versus non-berry season), despite reported differences in total number of mortalities (Benn and Herrero, 2002). Benn and Herrero (2002) found that a high proportion of mortalities occurred in the berry season when bears were most likely to forage at low elevation sites for Canada buffaloberry, Shepherdia canadensis, fruits. Although grizzly bears were more likely to be ‘killed’ during the hyperphagic berry period when they were accessing habitats near humans (e.g., low elevation sites), these sites were spatially similar to those of other mortalities occurring in the non-berry seasons. This suggests that the spatial locations of mortality sinks (sensu Knight et al., 1988) were consistent and only the number (rate) of mortalities varied by season. For the sub-adult male and non-sub-adult male comparison, we found that sub-adult males tended to be ‘killed’ further from access and edge features when compared with non-sub-adult males, although variation in distance to access for sub-adults was high suggesting that animals were ‘killed’ both near and away from access features. Although we expected sub-adults to be further from edges through aggressive displacement by adult males (McLellan and Shackleton, 1988), we were surprised to find sub-adult male mortalities further from access features where you would expect most mortality events to occur regardless of sex-age class. Perhaps, sub-adult males were simply more broadly distributed across the landscape and this was reflected in mortality locations. Finally, the legal harvest versus non-legal harvest comparison revealed that legal harvests were further from edges and access features. This suggests that during the hunting season grizzly bears are further from edges and access or hunters were accessing more remote areas during the hunt.

For the global data set, the random-based mortality distribution model and the radiotelemetry-based mortality risk model revealed similar mortality patterns that were largely consistent with the literature and expected distribution of bears. Grizzly bear mortalities were positively associated with access, water, and edge features (e.g., nearer to those features or a negative coefficient). Previous research in the region has shown that bears select edge habitats and streamside areas (Nielsen et al., 2002; Theberge, 2002), but we also suspect that humans are more likely to be in these sites as well, thereby increasing the frequency of contact between bears and humans (Mattson and Merrill, 1996a; 1996b). Distance to access features, on the other hand, is more likely to describe the distribution of humans in space. Where bear habitat co-occurs with human access, however, interactions between bears and humans will escalate thereby increasing risk of human-caused mortality to bears. Although previous research in the area has shown positive associations between grizzly bear occurrence and both terrain ruggedness and the vegetation index greenness (Mace et al., 1999; Nielsen et al., 2002; Stevens, 2002; Theberge, 2002), we found negative associations for models describing mortality sites. Our models did not consider, however, the overall spatial pattern or patchiness of greenness like that of Stevens (2002), and thus may reflect the strong association of mortalities with edges, stream side areas, and roads, where pixel values for greenness are likely to be low. Likewise, for terrain ruggedness, we suspect that terrain patterns in mortalities is likely to be related more with human distribution than grizzly bear distribution as humans are less likely to venture into more rugged terrain, at least when compared to grizzly bears. Finally, for land-cover type classes, shrub (including avalanche) habitats were consistently more likely to have mortalities than the reference category closed conifer stands. We feel this reflects the strong concentration of bears within shrub and avalanche areas (Theberge, 2002).

Overall, global models describing the distribution of mortality risk were predictive and significant based on the occurrence of independent grizzly bear mortalities withheld for model validation. This suggests that mortalities were well described and predictable using readily available terrain, human, and vegetation GIS...
data. This is further supported by the methods and results observed by Johnson et al. (2005) in the spatial description of grizzly bear survival in the Greater Yellowstone Ecosystem. Although our models were not based on the more powerful Cox regression methods (Cox and Oakes, 1984) for survival (1-mortality), as we did not track exposure and ultimately death for individual animals, our mortality risk model would likely closely match ranks from a survival model. Baseline survival functions from other studies might be used to scale our predictions. The fact that Johnson’s (et al., 2005) survival model for Yellowstone and our mortality risk model for the CRE qualitatively provide similar responses to similar types of GIS data suggest that information from other areas can readily be used to describe areas of grizzly bear mortality risk, as human behaviour ultimately causing grizzly bear deaths appears to be consistent.

**MANAGEMENT IMPLICATIONS**

Conservation models describing grizzly bear mortality locations in the CRE of Canada are needed for management and conservation planning. As would be expected, landscape attributes relating to human use, such as roads, trails, and terrain, correlated well with the locations of human-caused grizzly bear mortalities. Spatial mortality models, as those presented in this paper, can be used for management of humans in grizzly bear territories and the identification of potential restoration (road access control or deactivation) sites. Moreover, incorporation of risk models with existing animal occurrence models (e.g., Nielsen et al., 2002; 2003) may prove useful for assessments of population viability (Boyce and McDonald, 1999) and attractive sink dynamics (Delibes et al., 2001; Naves et al., 2003). We suggest that risk models be integrated with habitat models for identifying key habitat sinks and secure areas for active management and protection respectively.

Management and mitigation of potential habitat sinks may be necessary, at minimum during essential activities such as the hyperphagic berry period (August to October) or the spring limited entry bear hunt when the majority of animals are at high risk and killed by humans (Benn and Herrero, 2002). Concurrently, education programmes for the public and hunters may be necessary to reduce bear-human conflicts (Schirokauer and Boyd, 1998). Finally, management policies regarding problem wildlife may need further modification and/or examination of population impacts. Numerous animals were lost to the CRE by relocation and/or problem wildlife mortalities (Benn, 1998). The number of management actions a grizzly bear received increased substantially the risk of mortality (Boyce et al., 2001; Johnson et al., 2005). This suggests that behavioural patterns exhibited by some bears may place them at greater risk and those management policies and actions for these animals were not successful in ultimately reducing mortality. Managers should consider alternatives to animal relocation, such as aversive conditioning, while striving to minimize habituated and problem animals from first developing. Even with well-intended management plans, maintenance of viable grizzly bear populations in southern Canada is increasingly difficult given the rapid growth in human population, land use pressure, and recreation within grizzly bear range (McLellan, 1998). Addressing access management for grizzly bear populations, now being considered for threatened status by the Alberta government, may be necessary to stem localized mortality sinks. Implementation of human recreation and waste management policies in the National Parks has reduced local human-bear conflicts (Benn, 1998). We found that relatively little of the landscape was secure from human-caused mortality for grizzly bears. This would be most directly remedied by decreasing human access.

**LITERATURE CITED**


6.5 Modelling spatial distribution of human-caused grizzly bear mortalities — S. Nielsen et al.

FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005


6.6 SPATIAL AND TEMPORAL ANALYSIS OF HUMAN-CAUSED GRIZZLY BEAR MORTALITIES AND THEIR DENSITY IN THE CENTRAL ROCKIES ECOSYSTEM, 1972/78–2002

Stephen Herrero, Scott Jevons, and Bryon Benn

ABSTRACT
We analyzed records of 686 human-caused grizzly bear mortalities that occurred 1972–2002 in the Central Rockies Ecosystem (CRE). Our analysis focused on 106 human-caused female mortalities with acceptably accurate locations in Alberta, and 129 in British Columbia. Using a geographical information system (GIS) we analyzed the human-caused, female grizzly bear mortality densities for 2 time periods for each province: 1972–1989 and 1990–2002 for Alberta, and 1978–1989 and 1990–2002 for British Columbia. We present detailed geographic descriptions of areas having identifiable concentrations of human-caused female mortalities for each time period. The average number of human-caused female mortalities per year and the number of mortality concentration areas increased over time in BC and decreased in Alberta. We suggest that area specific mortality information and its changes over time should be a consideration in management decisions related to human-caused grizzly bear mortality and habitat. Four of the areas that had concentrated human-caused female mortalities over some of their extent were shown in another study to also have a high probability of selection by females. These areas were: 1) around the hamlet of Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area and south to and including the Burnt Timber drainage, 3) around Banff townsite and, 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. These areas that are attractive to female grizzly bears also have significant risk of death for them. They are candidates for management action aimed at grizzly bear conservation. Using GIS generated maps we also illustrated the geographic distribution of a number of variables known to be associated with grizzly bear mortality. These variables were: access, the location of grizzly bear and ungulate hunting, the location of protected areas, and land ownership. Understanding the relationship between these variables and human-caused grizzly bear mortality could help to geographically and jurisdictionally focus grizzly bear conservation efforts.

INTRODUCTION
Demographic vigor exists when a population is increasing or at least maintaining itself. The most important demographic parameter that supports vigorous populations of grizzly bears is a high survival rate for independent, especially adult, female bears (Knight and Eberhardt 1985, Eberhardt 1990, Garshelis et al. 2005). A year to year adult female survival rate of at least 92% has been reported for all Rocky Mountain grizzly bear populations estimated to be stable or increasing (Weaver et al. 1996). Managers of grizzly bear populations need knowledge of variables influencing mortality to be able to evaluate decisions that would influence demographic vigor.

Univariate analysis to identify variables associated with grizzly bear mortality in the Central Rockies Ecosystem (CRE) found that 98% (627 of 639) of recorded mortalities, 1971–1996, were human-caused (Benn 1998). Eighty-five percent of 462 human-caused deaths with known locations occurred within 500 m of roads or settlements, or within 200 m of trails. Deaths were concentrated in certain areas such as around the Banff townsite, the hamlet of Lake Louise, along the Trans Canada Highway, and along roads and trails accessing many valley systems throughout the CRE (Benn 1998, Benn and Herrero 2002). In Banff National Park, 1971–1998, 100% (95 of 95) grizzly bear mortalities with known locations were close to roads, trails or settlements (Benn and Herrero 2002).

Subsequent, multivariate analysis of grizzly bear mortality data for the Alberta (including Banff National Park) portion of the CRE was used to model the distribution of grizzly bear mortalities, 1971–2002 (Nielsen et al. 2004). Predictor variables included landscape attributes as well as variation in location among seasons, sex, sex-age class, and mortality type. Grizzly bear mortalities were concentrated in 3 main regions of the CRE: (1) Lake Louise; (2) Banff town site; and (3) Alberta Provincial lands near the Red Deer River. Some
level of mortality risk occurred throughout the study area. There was little secure habitat. There was no evidence for environmental differences in mortality locations between sexes or season, but strong differences in sub-adult male and legal harvest locations. Sub-adult male and legal harvest mortalities occurred further from access and vegetation edges than did all other sex-age classes and mortality types. Models describing the relative risk of bear mortalities were positively associated with access, water, and edge features, while negatively associated with terrain ruggedness and greenness (habitat quality surrogate) indices.

The objective of this research was to further analyze spatial and temporal aspects of grizzly bear mortality data in the entire CRE. We geographically locate and illustrate grizzly bear mortalities and assess changes over time. We map environmental variables known to be associated with grizzly bear mortality. We offer spatially-based management implications that could be used to help support levels of grizzly bear mortality conducive to demographic vigor.

METHODS

We used government records to determine the locations where human-caused grizzly bear mortalities and removals (hereafter called mortalities) occurred in the Alberta (including Banff National Park) and British Columbia (including Yoho National Park) portions of the Central Rockies Ecosystem, 1972 (Alberta), 1978 (British Columbia) – 2002. We did additional research to improve location accuracy where possible (Benn 1998, Benn and Herrero 2002, Chapter 6.4, this report). Mortality locations were mapped using ArcGIS© version 8.3 software and were displayed for 1972–2002 for all known dead bears.

We further analyzed human-caused female grizzly bear mortality locations in Alberta and British Columbia. We divided data into 2 time periods, 1972/1978–1989 and 1990–2002. These periods were chosen because in Alberta the national parks had closed previously open landfill sites during the 1980s and the Province of Alberta implemented more conservative management practices at the same time period, formally establishing the new policy in 1990 with publication and application of its grizzly bear management plan (Nagy and Gunson 1990). British Columbia replaced open garbage dumps with bear resistant landfill sites in the mid 1990s.

Human-caused mortality locations for females from Alberta and BC were analyzed separately, in each case using a moving window and ArcGIS© version 8.3 software to determine mortality density. For mortality locations in Alberta we used a moving window size equal to the mean home range size, 520 km², found for adult female grizzly bears trapped in the Bow River Watershed of Alberta, 1994–2002 (Chapter 9, this report). For mortality locations in British Columbia we used a moving window size of 103 km², the mean home range for adult female grizzly bears studied in this more productive habitat (John Woods, Parks Canada, Revelstoke, B.C., unpublished data). Adult female-sized home range windows were used to analyze mortality density since they reflected a geographic extent where mortality for an adult female might occur. While these windows were useful for representing mortality density they did not represent specific home range areas for individual females.

For Alberta we were able to overlay the mortality density map and a map of probability of occurrence of adult females (see Chapter 10.3, this report). This allowed us to identify the human-caused mortality risk associated with areas that an RSF model predicted female grizzly bears would be attracted to.

We also used ArcGIS© version 8.3 to map spatial/landuse variables previously found to be associated with grizzly bear mortality risk in the CRE. These landuse variables included: access, grizzly bear hunting, ungulate hunting, protected areas, and land jurisdiction.

RESULTS

Human-caused adult male and female grizzly bear mortalities: There were 686 human-caused mortality records with locations, 235 recorded as females, and 57 records with no locations. Fourteen of the 57 records were known females. Our mortality density calculations give minimal densities because of lack of locations for some recorded mortalities and lack of recording for others. Human-caused grizzly bear mortalities, including both males and females, were widely distributed throughout the CRE including areas protected from grizzly bear hunting (Figure 1).
Human-caused adult female grizzly bear mortalities in Alberta: There were more human-caused female mortalities in Alberta (including Banff National Park), 1972–1989, N=79, 4.4/ year than there were 1990–2002, N=31, 2.2/ year.

During 1972–1989 we determined geographic locations where 75 of the 79 recorded human-caused mortalities occurred. We identified 6 geographic areas where human-caused female mortality density was ≥0.28 mortalities/year (Figure 2, Table 1). This was equivalent to a minimum of 5 human-caused female grizzly bear mortalities in 18 years.
Figure 2. Human-caused female grizzly bear mortality locations and densities for Alberta, Central Rockies Ecosystem: 1972 to 1989.

<table>
<thead>
<tr>
<th>AREA (see maps)</th>
<th>DESCRIPTION</th>
<th>Density females killed per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta 1972 to 1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Hamlet of Lake Louise and vicinity with density decreasing with distance from the hamlet</td>
<td>0.72</td>
</tr>
<tr>
<td>b</td>
<td>Banff townsite and the vicinity of the Cascade landfill and Two Jack Lake Campground</td>
<td>0.50</td>
</tr>
<tr>
<td>c</td>
<td>Area south of the Red Deer River and east of the Forestry Trunk Road (Highway 734), in particular the Panther River and tributaries, Dogrib and Sheep creeks</td>
<td>0.22 - 0.56</td>
</tr>
<tr>
<td>d</td>
<td>South of and including Waiparous Creek; along the Ghost River and south to and including Broken Leg Lake</td>
<td>0.22 - 0.56</td>
</tr>
<tr>
<td>e</td>
<td>Along Lineham Creek; along McPhail Creek, and also along Etherington and Cataract creeks</td>
<td>0.33</td>
</tr>
<tr>
<td>f</td>
<td>Area between Canary Creek and the south Ram River</td>
<td>0.28</td>
</tr>
<tr>
<td>Alberta 1990 to 2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Lake Louise on the Trans-Canada Highway and in the developed area</td>
<td>0.62</td>
</tr>
<tr>
<td>b</td>
<td>Near the YalHa Tinda federal government ranch</td>
<td>0.31</td>
</tr>
<tr>
<td>c</td>
<td>Evan-Thomas Provincial Recreation Area and the area spanning Marmot Basin and Nakiska</td>
<td>0.31</td>
</tr>
<tr>
<td>d</td>
<td>Evan-Thomas Creek and headwaters and Piper Pass (Little Elbow Creek Headwaters Trail)</td>
<td>0.23</td>
</tr>
<tr>
<td>British Columbia 1978 to 1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Headwaters of the Palliser River and the Height of the Rockies Provincial Park</td>
<td>0.33</td>
</tr>
<tr>
<td>b</td>
<td>Within about a 5 km radius of Elkford</td>
<td>0.42</td>
</tr>
<tr>
<td>c</td>
<td>Within 5 km north (including Rock Creek Canyon) and 9 km east of the confluence of the North and East White rivers</td>
<td>0.33</td>
</tr>
<tr>
<td>d</td>
<td>In the upper Elk Valley</td>
<td>0.25</td>
</tr>
<tr>
<td>e</td>
<td>Along the Blueberry drainage and especially its headwaters</td>
<td>0.25</td>
</tr>
<tr>
<td>British Columbia 1990 to 2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Elkhorn landfill and near the community</td>
<td>0.85</td>
</tr>
<tr>
<td>b</td>
<td>North Windermere Creek and at the Windermere landfill</td>
<td>0.46</td>
</tr>
<tr>
<td>c</td>
<td>Upper reaches of the Albert River</td>
<td>0.38</td>
</tr>
<tr>
<td>d</td>
<td>Upper Elk Valley adjacent to Elk Lakes Provincial Park</td>
<td>0.38</td>
</tr>
<tr>
<td>e</td>
<td>Upper Elk Valley, in and adjacent to Height of the Rockies Wilderness Area</td>
<td>0.38</td>
</tr>
<tr>
<td>f</td>
<td>North White River and as far north as Nipakoo and Nilsuka Creeks</td>
<td>0.38</td>
</tr>
<tr>
<td>g</td>
<td>Vicinity of Pinnacle and Luxor creeks</td>
<td>0.31</td>
</tr>
<tr>
<td>h</td>
<td>Upper reaches of the Blueberry River</td>
<td>0.23</td>
</tr>
<tr>
<td>i</td>
<td>Near Donald Station (mouth of Wahtabit Creek), with mortalities also extending along the Columbia reach and Kinbasket Lake</td>
<td>0.23</td>
</tr>
<tr>
<td>j</td>
<td>Near Moose Creek in the vicinity of Wolfenden's cabin in the Beaverfoot Valley</td>
<td>0.23</td>
</tr>
</tbody>
</table>

During our most recent period of analysis, 1990 – 2002, we had geographic locations for 31 human-caused female mortalities and we identified 4 geographic locations where mortality density was ≥ 0.23 mortalities/year (Figure 3, Table 1). This was equivalent to a minimum of 3 mortalities in 13 years.
6.6 Mortality density in the Central Rockies Ecosystem, 1972/78 – 2002 — S. Herrero et al.

**Figure 3.** Human-caused female grizzly bear mortality locations and densities for Alberta, Central Rockies Ecosystem: 1990 to 2002.

**Adult female grizzly bear mortalities in British Columbia:** In BC, 1978–1989, there were N=51, 4.3/year, human-caused female mortalities. In BC, 1990 – 2002, mortalities increased and there were N=78, 6.0/year. During 1978 – 1989 we identified 5 geographic locations where human-caused female grizzly bear mortality density was ≥ 0.25 mortalities/yr (Figure 4, Table 1). This was equivalent to a minimum of 3 mortalities in 12 years.
During our most recent period for analysis, 1990 – 2002, we identified 10 geographic locations where human-caused female grizzly bear mortality density was $\geq 0.23$ mortalities/year (Figure 5, Table 1). This was equivalent to a minimum of 3 mortalities in 13 years.
Mortality density and geographic areas with a high probability of selection: In another study four geographic regions in the CRE were identified where there was a concentration of landscapes having a high probability of selection by adult female grizzly bears (Chapter 10.3, this report). These areas were: 1) around the hamlet of Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area and south to and including the Burnt Timber drainage, 3) around Banff townsite and, 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. Each of these areas we also identified as having concentrated...
mortalities over some of their extent, although the Banff townsite area only showed concentrated mortalities during the 1972–1989 period.

The location of access (linear corridors) in the CRE (Figure 6): Human landscape access by roads open to motorized vehicles, or trails/closed roads open to humans on foot, is extensive in the CRE. In Alberta, outside of Banff National Park, access is often related to previous seismic exploration or development with some access related to public transportation roads and to forestry.

Figure 6. Current access (linear corridors) within the Central Rockies Ecosystem.
In Banff, Yoho and Kootenay National Parks there is major, high speed motorized vehicle access and also extensive trail networks. In British Columbia, outside of the national parks, vehicle access is associated with public transportation roads and forestry roads open to the public.

The location of grizzly bear hunting within the CRE (Figure 7): Most grizzly bear hunting in the Alberta portion of the CRE occurs north of the Bow River and adjacent to Banff National Park. Grizzly bear hunting is not legal in the national parks nor in Kananaskis Country. In BC grizzly bear hunting is legal on most provincial land outside of national parks. Grizzly bear hunting is legal in BC provincial parks in the CRE.

![Figure 7. Grizzly bear hunting within the Central Rockies Ecosystem.](image)

The location of ungulate hunting within the CRE (Figure 8): Ungulate hunting occurs on most provincial land outside of national parks where no hunting is allowed. There is no ungulate hunting in a few provincial parks in Alberta in the CRE and in small ecological reserves in Alberta and BC.

The location of protected areas within the CRE (Figure 9): The core of the CRE is formed by national parks where hunting and resource extraction are not permitted. Provincial Parks in Alberta and BC mostly allow hunting as noted but do not allow resource extraction. Outside of national and provincial parks and other protected areas there is extensive grizzly bear habitat in the CRE in Alberta and BC on multiple-use, non-protected land.

Land ownership in the CRE (Figure 10): Relative to the size of the CRE only a small fraction of land is privately owned or designated as First Nation Reservation.
Figure 8. Ungulate hunting within the Central Rockies Ecosystem.

Figure 9. Protected areas within the Central Rockies Ecosystem.
DISCUSSION

Our spatial and temporal analysis of human-caused grizzly bear mortalities focused on mortalities of females because of their critical role in reproduction and demographic vigor. Changes in mortality density and average number of known mortalities per year between the times we studied do not necessarily reflect changes in the abundance of grizzly bears. The average number of human-caused, female mortalities per year and the number of mortality concentration areas increased over time in BC and decreased in Alberta. Human-related variables influencing mortality and abundance include motorized access, grizzly bear and ungulate hunting, peoples’ food and garbage attractants, etc. all of which have changed in the CRE during our period of study. The only scientifically rigorous assessment of population status for even a portion of the CRE was carried out in the Bow River Watershed (Garshelis et al. 2005). This study reported a 90% probability that this population had a positive growth rate during the period 1994–2002.

Our spatial and temporal analysis of human-caused female grizzly bear mortalities identified geographic areas where mortalities have occurred and areas of relatively high mortality density. We also illustrate how mortality density has changed geographically over time. This information is intended to inform land and grizzly bear management decisions that might influence human-caused grizzly bear mortality.

The widespread distribution of the 686, human-caused, grizzly bear mortalities and their locations, 1972/78–2002, illustrates the low habitat security that is typical for grizzly bears in the CRE (Gibeau et al. 2001, Nielsen et al. 2004, Chapter 12, this report). Some of the ESGBP research in the CRE found no differences between environmental characteristics of sites where male or female grizzly bears died (Nielsen et al. 2004). Perhaps the scale of analysis was too coarse to detect differences. Benn and Herrero (2002) found that 80% of recorded adult grizzly bear mortalities, 1985–1998, in Banff and Yoho National Parks were females, showing that adult females were more likely to die inside of national parks than were adult males. ESGBP demographic research found that 90% of human-caused adult male grizzly bear mortalities of bears radiomarked in the Bow River Watershed occurred outside of national park boundaries (Garshelis et al. 2005). These findings show that certain variables such as whether an area is a national park co-vary with the probability of female versus male death.
Demographic analysis by the ESGBP (Garshelis et al. 2005) and other researchers (Eberhardt 1990) has demonstrated that a high rate of adult female survival is critical to population growth or maintenance. Such a high rate of adult male survival is not necessary for population growth or persistence (Eberhardt 1990, Garshelis et al. 2005). With this in mind we focused our spatial and temporal analyses of grizzly bear mortality locations on independent females.

While adult female mortalities were widely distributed in our large study area there were also areas of geographically concentrated mortality. The existence of areas of concentrated adult female mortalities suggests the possibility that in these areas population sink conditions may exist. Additional demographic research would be needed to determine this.

Other research identified 4 areas in the Alberta portion of the CRE that had a concentration of high probabilities of adult female occurrence (Chapter 10.3, this report). These areas were also identified as having concentrated adult female grizzly bear mortality, although one area, the Banff townsite only showed this during the 1972–1989 period of analysis. Nielsen (2004) has referred to such areas as attractive population sinks. He and we believe they are areas where management action to reduce human-caused adult female mortalities could enhance population status.

Research has demonstrated a strong association between motorized access and grizzly bear mortality probability (McLellan 1989, Mace et al. 1996, Benn and Herrero 2002). The well developed, motorized-access linear corridors present throughout the CRE (Figure 6) are a fundamental factor associated with human-caused grizzly bear mortalities (Benn 1998, Benn and Herrero 2002, Nielsen et al. 2004, Chapters 6.3, 6.4, this report). In Alberta there are over 1,000,000 km of linear features (major roads, minor roads, hiking/biking trails, transmission lines, seismic, pipelines, etc.) (Chapter 13, this report). This volume of linear corridors makes it difficult to provide for grizzly bear habitat security. This is true but to a lesser extent in BC (Chapter 12, this report).

Grizzly bear hunting is permitted in most portions of the CRE where the species occurs outside of national parks. The exceptions to this are areas south of and just north of the Bow River. Here, concern for grizzly bear abundance has led to grizzly bear hunting closures. As we continue to develop access and landuse in the currently hunted portions of the CRE in Alberta north of the Bow River, then further hunting closures should be expected as grizzly bear populations decline in response to multiple and increasing causes of mortality such as currently exist south of the Bow River (Chapters 6.2 and 6.4, this report).

Ungulate hunting and associated carcasses leading to encounters with grizzly bears is a major factor associated with grizzly bear mortalities in the Greater Yellowstone Ecosystem (Servheen et al. 2004). ESGBP research has also shown it was a significant factor in the Bow River Watershed (Chapter 6.2, this report).

The shape of protected areas in the CRE is not ideal from a grizzly bear conservation perspective. The shape is longer than it is wide and the northern and southern ends of the protected areas have narrow protected area “appendages.” These shapes overall create a large area of contact with non-protected areas and this increases the probability of grizzly bear mortality.

In the Greater Yellowstone Ecosystem private lands account for a disproportionately large number of the reported grizzly bear-human conflicts (Gunther et al. 2004, Servheen et al. 2004). While there is little private land in occupied grizzly bear range in the CRE, some of this, such as the town of Canmore, has recently shown high mortality risk for grizzly bears. First Nation Reservation lands also are only a small part of the CRE but they too have a disproportionately high mortality risk (Chapters 6.2 and 6.4, this report).

**MANAGEMENT IMPLICATIONS**

Knowledge of locations where human-caused, female grizzly bear mortalities have been concentrated and their changes over time may be used to inform land and grizzly bear management decisions. Managers may chose to carefully monitor mortalities in these areas and in some cases take steps to decrease mortalities. Lake Louise is one such area where there has been long term, relatively high mortality density. Because it is located in Banff National Park steps should and are being taken to decrease female grizzly bear mortalities. Success needs to be demonstrated. This can be done by monitoring and regularly analyzing mortalities and achieving desired female mortality rates.

Where mortalities are concentrated in landscapes with a high probability of adult female occurrence, then to support grizzly bear conservation management, actions should enhance adult female survival. Our
results for the Alberta portion of the CRE identified 4 such areas. We recommend a high priority be given to ensuring human-caused adult female mortality in each of these areas is at least sustainable. These areas have varying degrees of habitat protection. Consideration should be given to improving this in all 4 areas including Banff National Park. The most obvious and perhaps urgent such area to be considered for additional protection is the Ya Ha Tinda/Red Deer River area and south to and including the Burnt Timber drainage.

Access management is a key issue in planning for grizzly bear persistence. Female grizzly bear mortalities were located disproportionately near motorized access (Benn 1998, Benn and Herrero 2002, Nielsen et al. 2004). The lack of high levels of habitat security for grizzly bears in the CRE could be addressed through access management. In portions of the CRE where grizzly bear hunting exists and there is area concentrated mortality, specific restrictions, such as access control, could be used to decrease human-caused female mortality and to encourage population growth.

Knowledge of the spatial distribution of mortalities, areas where they concentrate and changes over time, could also serve as input in deciding where to locate hair-snagging grids for DNA-based population estimation and range determination. By targeting areas where female grizzly bear mortalities were concentrated in the past, but no longer are, research could suggest the extent to which such areas are currently occupied.

**LITERATURE CITED**


CHAPTER 7

EAST SLOPES GRIZZLY BEAR FRAGMENTATION BASED ON GENETIC ANALYSES
7. EAST SLOPES GRIZZLY BEAR FRAGMENTATION BASED ON GENETIC ANALYSES

Michael Proctor

ABSTRACT
Population fragmentation is a major concern in viability of many wildlife species. Grizzly bears in southwestern Canada occupy peninsular shaped habitats corresponding to major north/south oriented mountain ranges resulting from human settlement patterns in major valleys. In an effort to explore potential fragmentation of grizzly bears, I gathered genetic samples in southwestern Canada between 1996 and 2001 including grizzly bears from the Eastern Slopes Grizzly Bear Research Project. Using genetic tools I explored bear movement across Highway 1 and between the East Slope area and adjacent geographic areas. The movement trends I found in the East Slopes area across Highway 1 were consistent to those I found in my regional study area, that is, limited evidence for female movement through human transportation and settlement corridors with significant amounts of human disturbance and consistent evidence of male movement. The amount of genetic differentiation I found across Highway 1 was low relative to other areas within my larger study area. I did find evidence of male and female movement and/or dispersal across the continental divide to the south across Elk Pass into British Columbia. I found less evidence of movement across the continental divide north of Highway 1 into British Columbia. These results indicate that genetic connectivity across Highway 1 is being mediated by male movement while demographic connectivity is being fractured (i.e. females’ movement is limited). Considering the peninsular shape of the remaining distribution of grizzly bears in southwestern Canada, the long-term fragmentation potential from the major east-west highways (1, 3, and 16) should probably be considered for management attention.

INTRODUCTION
Population fragmentation is a major concern in viability of many wildlife species (Wilcox and Murphy 1985). Grizzly bears at the trailing edge of their contracting North American distribution occupy peninsular shaped habitats corresponding to major north/south oriented mountain ranges (McLellan 1998). This distribution in southwestern Canada has resulted primarily from human settlement patterns in major valleys. At the continental scale, the bears occupying this region (Fig. 1) are important because they represent the front lines of any further range contraction that may or may not occur as human society continues to develop and yet endeavors to coexist with wildlife and large carnivores in particular. Human-caused mortality and fragmentation have been dominant forces responsible for this last century’s range contraction (Mattson and Merrill 2002). However, there has been a paradigm shift in human attitudes towards grizzly bears, and large carnivores in general, from that of competitive pest to deserving and respected members of a rich complex and relatively “natural” ecosystem. However, the question remains, is fragmentation of grizzly bears still occurring as a result of human activities, and if so, are there any potential trouble spots that require thoughtful management.

In an effort to explore potential fragmentation of grizzly bears, I gathered genetic samples in southwestern Canada between 1996 and 2001. Using genetic-based analyses I explored the following research questions. How do bears move between geographic areas in a mountainous landscape at a regional scale? Is there a difference in male and female movements? Does the human environment affect bear movements? Included in this study were grizzly bears captured and studied as part of the Eastern Slopes Grizzly Bear Research Project. This report discusses the results of this effort that relate to bears in the East Slopes area of the Canadian Rocky Mountains. The East Slopes study area is bisected by Highway 1, western Canada’s busiest transportation corridor. Highway 1 is one of three major transportation corridors to cross southwestern Canada with Highway 3 to the south and Highway 16 to the north. Proctor et al. (2002) report that Highway 3 and associated human settlements have fragmented grizzly bears in the southern Rocky Mountains. Gibeau (2000) found, using radio telemetry methods, that female grizzly bears have been fragmented across Highway 1. While there appears to be some occasional movement of females across the highway, most have died as a result, suggesting that successful migration may be limited (Gibeau 2000; Mueller 2001). Using genetic tools I explored bear movement across Highway 1 and between the East Slope...
area and adjacent geographic areas. In this report I discuss the East Slope grizzly bear movement and fragmentation within the Rocky Mountains, in relation to adjacent areas, and in a regional context.

METHODS

In my larger study of southwestern Canada I sampled approximately 850 grizzly bears in southwestern Canada across 100,000km² (Fig. 1). Sampling, genetic analysis, and spatial analysis are detailed in Proctor (2003). Here I provide a basic sketch of relevant methods and analyses. Within the East Slopes area I used samples from 90 bears (40 north of Highway 1 and 50 south of Highway 1, 36 males, 44 females and 10 unknown sex). Most samples were from research bears provided by M. Gibeau and S. Herrero, and several were hunter killed or problem wildlife bears provided by the Alberta Department of Natural Resources (B. McClymont). I generated 15-locus microsatellite genotypes for all individual bears (Paetkau et al. 1998), sexed unknown bears (Woods et al. 1999), and took efforts to reduce genetic errors as outlined in Woods et al. (1999).

I arbitrarily divided my broader study area into 15 “local populations” based on major mountain range boundaries (valleys) and major highways and associated human settlement patterns (Fig. 1) to look for patterns in bear movements between areas. “Boundary areas” separating 23 immediately adjacent local population pairs (including 3 “control” areas not delineated on Fig. 1) were tested for their permeability to bear movements. Genetic data within each geographic area were subjected to basic population genetics metrics to test the assumptions underpinning analysis methods including, conformance to assumptions of random mating as tested by Hardy-Weinberg equilibrium, linkage dis-equilibrium (non-linked, independent genetic markers), and heterogeneity of allele frequencies between areas. These tests were run within GENEPOP software (Raymond and Rousset 1995). I used several methods to explore movement patterns of grizzly bears within and between geographic areas, including population assignment tests (Paetkau et al. 1995; Pritchard et al. 2000), parentage analysis (Marshall et al. 1998), and genetic distance measures (DLR, Paetkau et al. 1997; FST, Hartl and Clarke 1997; Weir and Cockerham 1984). Assigning individuals as putative migrants between areas was done when individuals were 100 times more likely (100 times probability) to have originated from their source population than the population of capture according to an allele frequency-based assignment test (Paetkau et al. 1995). I also used multiple linear regression to explore associations between detected movement rates and variables that may influence those bear movements. The measurable variables entered into the regression were, average geographic distance between areas sampled, average summer traffic volumes, human settlement patterns (% no settlement measured linearly along boundary area), and human caused mortality within the “boundary areas” (18 km out from boundary centre). I also did a population cluster analysis letting the genetic data demonstrate where “clusters” of genetically similar bears occurred with no a priori assumptions of population membership.

RESULTS

Movement and genetic differentiation across Highway 1

The movement trends I found in the Banff National Park and East Slopes area were consistent to those I found in my regional study area. I found limited evidence for female movement through “boundary areas” where significant amounts of human disturbance were present and consistent evidence of male movement (Proctor 2003, Ch.3 in Thesis). Within the East Slopes area, I found evidence of male movement and/or dispersal and no evidence of female movement and/or dispersal across Highway 1. The amount of genetic differentiation I found across Highway 1 was low (ESN-ESS, $F_{ST} = 0.013$, Fig. 1, Table 1) relative to other areas within my larger study area. For instance, genetic differentiation across Highway 3 in the southern Rocky Mountains was 3 times higher (CRS-SRS, $F_{ST} = 0.035$, Fig. 1, Table 1)
Table 1. Summary of genetic differentiation in the East Slopes area as measured by F<sub>ST</sub>. Population pairs’ names and locations can be viewed on Figure 1. ESN and ESS are the areas north and south of Highway 1 in the East Slopes study area. NRW is the area west of ESN across the continental divide. FMF Foothills Model Forest study area is around Jasper National Park, CRS is the area in the Rocky Mountains north of Highway 3 and south of Elk Pass, and SRS is the area in the Rocky Mountains south of Highway 3.

<table>
<thead>
<tr>
<th>Pop Pairs</th>
<th>F&lt;sub&gt;ST&lt;/sub&gt;</th>
<th>Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESN-NRW</td>
<td>0.012</td>
<td>CD</td>
</tr>
<tr>
<td>ESN-ESS</td>
<td>0.013</td>
<td>Highway 1</td>
</tr>
<tr>
<td>ESN-FMF</td>
<td>0.027</td>
<td>Distance</td>
</tr>
<tr>
<td>ESS-CRS</td>
<td>0.028</td>
<td>CD</td>
</tr>
<tr>
<td>CRS-SRS</td>
<td>0.035</td>
<td>Highway 3</td>
</tr>
</tbody>
</table>

Figure 1. East Slopes study area in regional context of larger genetic-based movement and fragmentation study. East Slopes North and East Slopes South (ES South) areas are the primary focus of this report. Other outlined areas were also genetically sampled and boundaries are arbitrarily set for analysis purposes based on mountain boundaries, major highways and human settlement. Abbreviations are, Central Selkirks Southwest (CSSW and Southeast (CSSE), Jasper National Park (JNP), Banff (BNP), Kootenay (KNP), Yoho (YNP), Waterton (WNP), Glacier (GNP), Purcell Wilderness Conservancy (PWC), Goat Range Provincial Park (GRPP), Valhalla (VPP), Kokanee Glacier (KPP), and West Arm (WAPP).
Movement and genetic differentiation with adjacent areas

Continental Divide to the south – Elk Pass

I found evidence of male and female movement and/or dispersal across the continental divide to the south across Elk Pass into British Columbia. The genetic differentiation across the divide between these areas (ESS-CRS, $F_{ST} = 0.028$, Fig. 1, Table 1) was higher than that across Highway 1. The population cluster analysis suggested that this continental divide may be a mild natural fracture creating genetic structure across the continental divide.

Continental Divide to the north of Highway 1

I found less evidence of movement across the continental divide north of Highway 1 into British Columbia. I found no evidence of female movement and some male movement. The genetic differentiation across the continental divide north of Highway 1 was also low (ESN-NRW, $F_{ST} = 0.012$, Fig. 1, Table 1).

North to the Jasper National Park area (Foothills Model Forest)

I found evidence of 1 male putative migrant from the Jasper area into the East Slopes study area. While it is difficult to locate the true origin of this individual because many areas north of the East Slopes study area were not genetically sampled, there is evidence that this bear may have a parent-offspring relationship with an individual within the Jasper NP area. The genetic differentiation between the East Slopes bears living north of Highway 1 and those in the Jasper area is mild (ESN-FMF, $F_{ST} = 0.027$, Fig. 1, Table 1) and likely is a result of the geographic distance between the areas rather than any real barrier to bear movement.

Population Cluster analysis

Cluster analysis (STRUCTURE) found that the bears of the East Slopes area did not cluster among themselves as did bears in most other geographic areas within my study area. At the larger scale, I found evidence to cluster bears to the north and south of Highway 1 into two separate sub-population units based on the demographic fragmentation of limited female interchange (Proctor 2003, Ch. 4 in Thesis). I clustered the bears within the Rocky Mountains to the south of Highway 1 and north of Highway 3 as 1 sub-population unit and the bears north of Highway 1 with an tentative northern limit of Highway 16 (my data does not extend beyond highway 16) as separate sub-population units.

Genetic variability (heterozygosity)

I found average expected heterozygosity (an index to genetic variability) to be similar across Highway 1 and similar in the entire region.

DISCUSSION

My results are consistent with those of Gibeau (2000) who found limited female movement across Highway 1 using radio telemetry methods. This is consistent with other results I have found in the region, that is, in areas with some threshold level of human disturbance, I found very limited female movement through linear areas paralleling major highways (Proctor 2003). Multiple linear regression results suggest that human-caused mortality, heavy traffic volume, and average geographic distance between areas is associated with limited female movement (Proctor 2003 – Ch. 3 in Thesis).

In addition to the male bears identified to cross Highway 1 by the East Slopes project (Gibeau 2000), I found evidence of 2 more males crossing the highway. I have no evidence that male movement has been reduced due to human disturbance specifically in the Bow Valley. However, my regression results of the entire study area suggest that male movement is associated with human disturbance variables including human-caused mortality, human settlement, average geographic distance between areas, and to a lesser degree traffic volume (Proctor 2003 – Ch. 3 in Thesis). It does appear that male movement is being reduced in some areas but that human settlement may play a larger role in inhibiting male movements. The only area where I have no evidence of any male movement (Southern Selkirk Mountains within my larger study area) is also the only area that has continuous human settlement separating geographic areas. The relative lack of human settlement along Highway 1 through the National Parks, including Glacier NP in the Selkirk...
Mountains, may partially explain the low genetic differentiation across Highway 1 in the Rocky and Selkirk Mountains relative to other disturbed areas within my study area. However, I have a caveat to this conclusion. Signals of genetic differentiation mediated by fragmentation are driven by the process of genetic drift. Genetic drift occurs relatively slowly when effective population sizes are large, as may be the case for grizzly bear populations directly to the north and south of Highway 1 in the Rocky and Selkirk Mountains. Telemetry data suggests that males move regularly across Highway 1 in the Rocky and Selkirk Mountains, and the genetic data supports this observation. What the genetic data is not able to provide in this instance, is whether the observed levels of male movement are a reduction from past levels, due to the slow development of a genetic signal because of the relatively large population sizes. However, there are similar large populations north and south of Highway 3 in the Rocky Mountains to the south where the genetic differentiation is approximately 3 times greater (FST = 0.035) than that measured across Highway 1 (Proctor 2003). Both systems appear to have limited female movement.

These results indicate that genetic connectivity across Highway 1 is being mediated by male movement but demographic connectivity is being fractured (i.e. females’ movement is limited). I have no evidence that human disturbance affects females more than males but the impacts may be more prevalent on females because they naturally move and disperse less than males. In other words females, because of their tendency to move and disperse less than males (LeFranc et al. 1987; Blanchard and Knight 1991; Mace and Waller 1997; McLellan and Hovey 2001; Proctor et al. 2004), may be impacted more by linear human disturbance. On the other hand, females bearing offspring may naturally be more cautious in the presence of human disturbance and therefore be more affected. In the end, it seems clear that linear human disturbance is impacting female connectivity across human disturbed areas.

Cluster analysis (STRUCTURE, Pritchard et al. 1999) found that the bears of the East Slopes area did not cluster among themselves as did most geographic areas within my study area. These results suggest that there has been historic movement in and out of the East Slopes area or that the recent influx of translocated bears into the Rocky Mountains from the Selkirk Mountains to the west (Proctor and Neumeier 1996) has created this signal of genetic linkage. My data do not allow me to distinguish between these two hypotheses.

Cluster analysis indicated a potential natural filter across the divide to the south (Elk Pass) providing some genetic structure. This natural fracture is not complete by any means, as I found evidence of male and female movement across the continental divide into British Columbia in this region. South of Highway 1, I did not sample directly to the east of Banff NP on the British Columbia side of the divide, and therefore cannot comment on movement across the divide into BC other than across Elk Pass as mentioned above. North of Highway 1 I found evidence of male movement but no female movement across the divide into BC. While I did not have a complete sampling on both sides of the continental divide along its length, my results suggest that in areas with low passes, male and female movement occurs. The extent of this natural filter is likely variable along the divide depending on the ruggedness of terrain and the presence of passes. Other researchers have reported movement of bears across rugged areas along the divide but quantitative data is not available (B. McLellan pers. comm.)

While the cluster analysis found the bears in the Jasper NP area to cluster separately, the relatively large geographic separation between the sampling areas makes it difficult to reach conclusions about the amount of geneflow between the two areas. The cluster analysis is prone to clustering separate sampling areas that are separate by geographic distance that may not reflect a discontinuity in geneflow but rather more isolation by distance, or connectivity by a stepping stone model (Pritchard et al. 1999). However, the results from my larger study area did cluster similarly geographically separate areas with a sampling hiatus into a single cluster on two occasions. These results suggest that there may be some genetic structure between the Jasper and Banff bears that is not entirely caused by distance alone, although I have no hard evidence to support this conclusion.
Regional context and management implications

Fragmentation of grizzly bears in southwestern Canada has resulted in “sub-populations” of various sizes with varying degrees of connectivity between these population sub-units (Proctor 2003 – Ch. 4 in Thesis). In the Selkirk and Purcell Mountain ranges to the south and west of the East Slopes area (Fig. 1) several populations and sub-population units are vulnerably small with estimated sizes below 100 animals (Proctor 2003 – Ch. 2, 3, 4 of Thesis). Several other larger sub-populations have resulted from the development of genetic structure across a human-caused fracture that is accompanied by a lack of evidence for female exchange. One of these sub-populations is the area in the Rocky Mountains between Highways 1 and 3 within BC and Alberta. Clearly, demographic fragmentation is a conservation concern in these areas as human-caused mortality plays a dominant role in grizzly bear population dynamics in this region (McLellan et al. 1999), and large carnivores in general (Woodroffe and Ginsberg 1998). Less immediate is the demographic fragmentation occurring across Highway 1 mainly because the resulting population sub-units are relatively large. However, considering the peninsular shape of the remaining distribution of grizzly bears in southwestern Canada (Fig. 1), the long-term fragmentation potential from the major east-west highways (1, 3, and 16) should probably be considered for management attention. Human settlement patterns are difficult to reverse, therefore looking ahead and managing appropriate areas for linkage zones would be prudent. Special attention should be given to the movement needs of female bears. Regression results (discussed above) from my larger study implicate human settlement, traffic volume and human-caused mortality as having an influence on movement and fragmentation of grizzly bears in this region. To maximize connectivity across the Highway 1 corridor, managers should consider minimization of human-caused bear mortality and human settlement as management strategies. These are likely already formalized goals for human activity within the Rocky Mountain National Park region but my data may provide added impetus for reaching these management goals. Minimization of the effects of traffic volume may require adaptive management strategies encompassing the results of the existing monitoring of animal movement across existing under- and overpasses. If female grizzly bears begin to use these structures over time and survive to reproduce (providing functional connectivity), past management may be adequate. However, if poor movement rates of female grizzly bears persist, other more effective strategies may be required.

LITERATURE CITED


CHAPTER 8

NUTRITIONAL AND HORMONAL STATUS OF SOME EASTERN SLOPES GRIZZLY BEAR PROJECT BEARS AND POSSIBLE LINKS TO LOW REPRODUCTIVE OUTPUT
8.1 Nutritional and Hormonal Status of Some Eastern Slopes Grizzly Bear Project Bears and Possible Links to Low Reproductive Output

Stephen Herrero

INTRODUCTION

In the absence of other constraints the population density of grizzly bears in a given area is predicted to increase as a linear function of landscape productivity (Senft et al. 1987). Bears’ rate of reproduction varies across their range with varying availability of food (Ferguson and McLoughlin 2000). High seasonality of food availability and variation in foods available between years characterize bear populations found at high altitude or latitude. If reproductive success varies significantly between individuals and years then Ferguson and McLoughlin (2000) state that bet-hedging theory predicts a reduction in reproductive effort per year in order to live longer and reproduce more times, thereby sampling a larger number of reproductive conditions and increasing the number of offspring born in good conditions. Among interior populations of grizzly bears in North America, vegetational productivity (indexed by evapotranspiration), accounts for >90% of variation in age of first cub production with bears found in less productive areas first reproducing at later age (Ferguson and McLoughlin 2000).

Grizzly bears have one of the lowest reproductive rates of any terrestrial mammal (Bunnell and Tait 1981). For bears, reproductive output is directly related to body mass in the fall (Rogers 1976, Blanchard 1987, Stringham 1990, Schwartz and Franzmann 1991). With abundant nutritious foods supporting sufficient body mass litter sizes tended to be larger, age of first reproduction earlier, and intervals between litters shorter (Rogers 1977, 1987, Bunnell and Tait 1981, Stringham 1990). Mass needed for successful reproduction by female grizzly bears ranged between 95 and 200 kg (Stringham 1990). Heavier bears typically had the highest rates of reproduction. It is difficult for grizzly bear females to attain large mass if they fatten primarily on berries. Unless berry densities are high there may not be enough foraging time in a day to ingest sufficient berries to attain a large enough mass to reproduce (Welch et al. 1997). A high carbohydrate (berry), low protein diet also increases energy metabolism and this limits weight gain (Rode and Robbins 2000). Optimal weight gains for grizzly bears appear to occur with a diet where primary fattening foods include a combination of fruits, nuts and animal protein but not fruits alone (Mattson 1999, Rode and Robbins 2000, Felicetti et al. 2003).

There has been little study of nutrient availability for grizzly bears living in the ESGBP study area. Detailed study of seasonal availability of energy through foods can be used to understand reproduction and other aspects of grizzly bear ecology (Mattson 1999). Food habits of grizzly bears in the Cascade Valley portion (Rocky Mountain Front Ranges) of the ESGBP research area were studied 1976-1980 (Hamer 1985, Hamer and Herrero 1987a). The foraging season was short, reflecting a continental climate. High energy foods on which to fatten appeared restricted primarily to one berry species (Shepherdia canadensis) and the occasional availability of elk or other ungulates. Food availability may be better to the west of the Cascade Valley in the Rocky Mountain Main Ranges portion of the ESGBP study area. However, nutrient availability and significant seasonal fluctuation of nutrients throughout the year and year to year, probably limit reproductive potential and keep population densities relatively low (Wielgus and Bunnell 1994, Proctor 1998). Fire suppression in the Cascade Valley region was suggested to have resulted in decreased nutrient availability for grizzly bears (Hamer and Herrero 1987b). Since then prescribed fire may have improved habitat quality somewhat (Hamer 1996, 1999).

Other factors in addition to nutritional state are also thought to constrain reproduction in grizzly bears. Female grizzly bears must live to reproductive age and then survive through their reproductive years. For Rocky Mountain grizzly bear populations that were stable or increasing there was an adult female survival rate of at least 0.92 (McLellan 1989, Wielgus and Bunnell 1994, Eberhardt et al. 1994, Weaver et al. 1996, Garshelis et al. 2005). Another possible constraint on reproductive output is competition between sexes whereby males may displace adult females from productive habitat (Wielgus and Bunnell 1994, Mattson 2005).
1999). Female grizzly bears have also been shown to underutilize productive habitat as a result of its proximity to people’s developments or activities (Mattson et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et al. 1996, Gibeau 2000).

ESGBP research was conducted 1994-2002. Reproductive data were obtained from 30 female bears aged 6–27 years old. The project accumulated 143 bear-years of reproductive information on adult-age animals, and was able to back-fill another 12 bear-years. Demographic analysis showed this population had one of the lowest reproductive outputs of any population studied in North America (Garshelis et al. 2005). Average age of first reproduction of a surviving cub litter was 8.4 years, average litter size 1.84. Age of first reproduction is considered to be a reproductive parameter particularly sensitive to local conditions for bears (Noyce and Garshelis 1994, Ferguson and McLoughlin 2000). The combination of long inter-litter intervals (4.4-4.5 years) and small litter sizes gave a reproductive rate of 0.17 female offspring reaching independence per female per year. Considering also the effects of delayed age of first birthing, bears in this population had the lowest potential lifetime cub production of any Ursus arctos population yet studied (Garshelis et al. 2005). Low body mass for ESGBP females (mean 96 kg, Chapter 4, this report) probably contributed to low reproductive output (Stringham 1990).

In this section of the ESGBP final report we present preliminary findings regarding nutrition. We used a Body Condition Index (BCI) (Cattet et al. 2002) and reproductive hormone levels to compare the nutritional reproductive output (Stringham 1990). Low body mass for ESGBP females (mean 96 kg, Chapter 4, this report) probably contributed to low reproductive output (Stringham 1990).

In this section of the ESGBP final report we present preliminary findings regarding nutrition. We used a Body Condition Index (BCI) (Cattet et al. 2002) and reproductive hormone levels to compare the nutritional status of ESGBP bears with a more productive population found in and east of Jasper National Park in the Foothills Model Forest grizzly bear study area, northwest of the ESGBP population, along the eastern portion of Jasper National Park and the adjacent foothills (G. Stenhouse. Alberta Sustainable Resource Development, Hinton, Alberta, Canada, personal communication, 2003). We also used stable isotope analysis of hair to estimate the percentage contribution of plants and animals to grizzly bear diet.

**LITERATURE CITED**


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8.2 STUDY AREA AND TRAPPING LOCATION

Stephen Herrero

The ESGBP study area was the 41,000 km² Central Rockies Ecosystem (CRE), an area straddling the continental divide of Alberta and British Columbia (Komex 1995). All trapping of grizzly bears was done within the major eastern slopes portion of the study area, the Bow River Watershed of Alberta (Gibeau 2000). The climate is continental with long, cold winters and short, cool summers (Janz and Storr 1977). Vegetation development goes through major seasonal variations driven by snow cover during winter. Most of the landscape falls into relatively high elevation major ecoregions: montane (1300-1600 m), subalpine (1600-2300m) and alpine (>2300m). Topographic features include mountains with substantial unvegetated portions. Forty-eight percent of the Banff National Park portion of the study area was unsuitable for grizzly bear foraging, primarily because it was covered with rock, ice, water or bare soil (Gibeau et al. 2001). Less unusable habitat was found in Alberta portions of the study area such as Kananaskis Country (21% unusable). Major valley bottoms are the most productive areas and many of these have development such as highways, railway, and settlement. Additional details regarding the ESGBP study area can be found in Chapter 2 of this final report and Gibeau (2000).

LITERATURE CITED
8.3 COMPARISON OF SELECT HEALTH DATA BETWEEN THE EASTERN SLOPES (ESGBP) AND THE FOOTHILLS MODEL FOREST GRIZZLY BEAR PROJECTS (FMFGBP)

Marc Cattet, Nigel Caulkett, Mike Gibeau, Stephen Herrero, Janice Bahr, Judith Van Cleef, and Gordon Stenhouse

In effort to seek potential explanations for low cub production by Eastern Slope grizzly bears, a comparison of select health parameters was made between Eastern Slopes and Foothills Model Forest Grizzly Bear Project bears. The parameters considered were body condition as a reflection of nutrition and reproductive hormone levels as a reflection of reproductive function. The working hypothesis was that reduced reproductive output in Eastern Slopes grizzly bears is a result of low energy uptake causing diminished reproductive function.

Using the definition of body condition as the “combined mass of fat and skeletal muscle in an animal relative to its body size”, we estimated and compared the body condition of grizzly bears captured in both projects by the Body Condition Index or BCI (Cattet et al. 2002). BCI values are calculated as the standardized residuals from the regression of total body mass against a linear measure of size, body length, and range in value from −3.00 to +3.00. Eastern Slopes grizzly bears tended to be in poorer body condition than FMF grizzly bears captured at the same time of year, a difference that was most notable among adult males (Table 1).

Table 1. Comparison of Body Condition Index (BCI) values between the Eastern Slopes and Foothills Model Forest Grizzly Bear Projects for grizzly bears captured during either May or June.

<table>
<thead>
<tr>
<th>Sex (Age Class)</th>
<th>Body Condition Index(A) (mean ± SE; ([n]))</th>
<th>Statistical Significance(B) ((p))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESGBP</td>
<td>FMFGBP</td>
</tr>
<tr>
<td>Female (all ages)</td>
<td>-0.43 ± 0.13 [22]</td>
<td>-0.13 ± 0.13 [37]</td>
</tr>
<tr>
<td>- subadult (&lt; 5 yrs)</td>
<td>-0.59 ± 0.38 [6]</td>
<td>-0.25 ± 0.25 [16]</td>
</tr>
<tr>
<td>- adult (≥ 5 yrs)</td>
<td>-0.37 ± 0.11 [16]</td>
<td>-0.04 ± 0.13 [21]</td>
</tr>
<tr>
<td>Male (all ages)</td>
<td>-0.16 ± 0.23 [21]</td>
<td>+1.00 ± 0.22 [23]</td>
</tr>
<tr>
<td>- subadult (&lt; 5 yrs)</td>
<td>-0.45 ± 0.35 [9]</td>
<td>+0.47 ± 0.29 [10]</td>
</tr>
<tr>
<td>- adult (≥ 5 yrs)</td>
<td>+0.05 ± 0.31 [12]</td>
<td>+1.41 ± 0.29 [13]</td>
</tr>
</tbody>
</table>

\(^{A}\) Mean BCI values were compared between studies using a t-test for two independent samples.

\(^{B}\) Statistical significance was assigned when the probability of a Type I error was equal to or less than 0.05. Non-significant = ns, \(p \leq 0.001 = **\); and \(p \leq 0.001 = ***\).

As an index of reproductive function, blood serum concentrations of various reproductive hormones were compared between grizzly bears captured in the two studies (Tables 2 and 3). In both sexes, luteinizing hormone (LH) concentrations were significantly lower in Eastern Slopes bears than in FMF bears. In mammals, LH is secreted from cells of the anterior pituitary gland and stimulates development of the ovaries in females and the testes in males. Further, LH stimulates secretion of sex steroids from the gonads – estrogens (including estradiol) from the ovaries and testosterone from the testes. Diminished secretion of LH can result in failure of gonadal function which manifests in females as cessation of reproductive cycles and in males as failure in production of normal numbers of sperms. Although information is lacking on normal
serum concentrations of LH in grizzly bears, these results cannot be used to rule out the possibility of diminished reproductive function in Eastern Slopes bears, especially when considered in conjunction with body condition results (Table 1). In mammals, the function of the reproductive system is dependent on the availability of energy in the environment. In several species, fasting and caloric restriction have been shown to cause the suppression of LH secretion, a mechanism that probably prevents energy being wasted for reproduction (Caprio et al. 2001, Gong 2002).

Table 2. Comparison of reproductive hormone concentrations between the Eastern Slopes and Foothills Model Forest Grizzly Bear Projects for female grizzly bears captured by leg-hold snare during either May or June.

<table>
<thead>
<tr>
<th>Hormone (Units)</th>
<th>Serum Concentration(^A) (mean ± SE)</th>
<th>Statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESGBP ((n = 14))</td>
<td>FMFGBP ((n = 29))</td>
</tr>
<tr>
<td>Progesterone (ng/ml)</td>
<td>2.54 ± 0.63</td>
<td>2.82 ± 0.35</td>
</tr>
<tr>
<td>Estradiol (pg/ml)</td>
<td>1.06 ± 1.2</td>
<td>13.5 ± 1.0</td>
</tr>
<tr>
<td>Luteinizing hormone (ng/ml)</td>
<td>0.13 ± 0.05</td>
<td>0.39 ± 0.08</td>
</tr>
<tr>
<td>Testosterone (ng/ml)</td>
<td>0.28 ± 0.05</td>
<td>0.29 ± 0.04</td>
</tr>
</tbody>
</table>

\(^{A}\) Mean hormone concentrations were compared between studies using a \(t\)-test for two independent samples.

\(^{B}\) Statistical significance was assigned when the probability of a Type I error was equal to or less than 0.05. Non-significant = ns and \(p \leq 0.01 = **\).

Table 3. Comparison of reproductive hormone concentrations between the Eastern Slopes and Foothills Model Forest Grizzly Bear Projects for male grizzly bears captured by leg-hold snare during either May or June.

<table>
<thead>
<tr>
<th>Hormone (Units)</th>
<th>Serum Concentration(^A) (mean ± SE)</th>
<th>Statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESGBP ((n = 16))</td>
<td>FMFGBP ((n = 17))</td>
</tr>
<tr>
<td>Luteinizing hormone (ng/ml)</td>
<td>0.07 ± 0.04</td>
<td>0.33 ± 0.09</td>
</tr>
<tr>
<td>Testosterone (ng/ml)</td>
<td>0.85 ± 0.26</td>
<td>0.91 ± 0.22</td>
</tr>
</tbody>
</table>

\(^{A}\) Mean hormone concentrations were compared between studies using a \(t\)-test for two independent samples.

\(^{B}\) Statistical significance was assigned when the probability of a Type I error was equal to or less than 0.05. Non-significant = ns and \(p \leq 0.05 = *\).

Results from a comparison of body condition and reproductive hormone concentrations between Eastern Slopes and FMF bears cannot be used to disprove the hypothesis that reduced reproductive output (long interval between litters and low reproductive rate) in Eastern Slopes grizzly bears is a result of low energy uptake (especially in males) causing diminished reproductive function. Future research directions should include the assessment of body condition in a larger sample of bears, especially adults, and the assessment of reproductive function in female and male adult bears. Ideally, assessment of reproductive function should involve ultrasonographic examination of the gonads of both female and male bears, and spermatologic examination of semen samples collected from males. This data should be evaluated in relation to circulating concentrations of reproductive hormones measured in blood serum samples taken at the time of examination.

**LITERATURE CITED**


8.4 DIET OF SOME EASTERN SLOPES GRIZZLY BEAR PROJECT BEARS AS DETERMINED USING STABLE ISOTOPE ANALYSIS

Laura Felicetti, Charles T. Robbins, Stephen Herrero, and Madalena Pinto

Isotopic analysis of ESGBP grizzly bear hair was conducted to further comment on the hypothesis that low reproductive output might be due to low energy intake. Analysis of stable isotopes of carbon and nitrogen present in hair indicate the dietary contribution of plant versus animal tissue. Since hair is replaced each year in bears the values reflect the diet consumed during growth of the hair.

METHODS

Samples of hair were collected from all bears captured and sedated as part of the ESGBP. A sample of these was sent to Dr. Charles T. Robbins’ lab at Washington State University, Pullman, for isotopic analysis. Sample size was small, 5 adult female and 4 adult male bears. Isotope signatures vary geographically (Garten 1993, Chamberlain et al 1997) hence a herbivore baseline was required for the Eastern Slopes Grizzly Bear Project (ESGBP) ecosystem. Hair samples from ungulates killed 2001 to 2003 in Banff National park were provided by Parks Canada with the help of Dr. Todd Shury. The ungulates sampled included mule deer (Odocoileus hemionus), white-tailed deer (O. virginianus) and elk (Cervus elaphus). The isotope signatures of the ungulate hair were then used to develop herbivore baselines for the ESGBP study area.

Hair samples were treated with a 2:1 chloroform:methanol solution to remove oils, dried, and ground into a fine powder in liquid nitrogen (Hilderbrand et al. 1996). Samples were weighed into tin boats and analyzed for $\delta^{15}N$ by continuous flow methods using a Carlo Erba NC2500 elemental analyzer coupled to either a Micromass Optima mass spectrometer or a Finnigan Delta Plus XL mass spectrometer (Fry et al. 1992). $\delta^{13}C$ was not analyzed as all samples were expected to have a uniform, terrestrial, C3-based signature. Results are reported as per mil ratios (‰) relative to atmospheric N ($\delta^{15}N$) with internal laboratory standards calibrated against US Geological Survey 25 ($\delta^{15}N = -30.4‰$), and USGS 26 ($\delta^{15}N = 53.7‰$) values. Internal reproducibility based on hundreds of standards run over the last 5 years is ± 0.2‰.

Dietary meat calculations are as in Hilderbrand et al. (1996) in which each $\delta^{15}N$ is solved for the respective bear signature that would occur if that species had been consumed as the entire diet. The trophic enrichment (4.3 if consuming deer and 4.4 for elk) was then used to estimate the percent meat represented by the difference in each bear’s $\delta^{15}N$ above the herbivore baseline represented by the mean ungulate signature.

RESULTS AND DISCUSSION

The ungulates had significantly different $\delta^{15}N$ signatures (mule and white-tailed deer = 5.6±1.2, n=15; elk = 3.6±1.2, n=9). When using the deer baseline, the grizzly bear population is estimated to be entirely herbivorous (Table 1). When using the elk baseline, meat is a more significant percent of the assimilated diet (Table 1).
Table 1: Male and female grizzly bear isotopic values and their implications regarding percentage composition of plant and animal matter in diet.

<table>
<thead>
<tr>
<th>ESGBP #</th>
<th>ESGBP Bear Information</th>
<th>δ¹⁵N</th>
<th>Deer – based¹</th>
<th>Elk – based²</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>Adult male grizzly #10.</td>
<td>4.6</td>
<td>0 100</td>
<td>23 77</td>
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<td></td>
<td>April 19, 1997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Adult male grizzly #12.</td>
<td>5.7</td>
<td>2 98</td>
<td>48 52</td>
</tr>
<tr>
<td></td>
<td>May 17, 1994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Adult male grizzly #14.</td>
<td>5.7</td>
<td>2 98</td>
<td>48 52</td>
</tr>
<tr>
<td></td>
<td>June 1994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Adult male grizzly #42.</td>
<td>4.7</td>
<td>0 100</td>
<td>25 75</td>
</tr>
<tr>
<td></td>
<td>June 15, 1997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male Mean ± 1 SD</td>
<td>5.2+0.6</td>
<td>1+1 99+1</td>
<td>36+14 64+14</td>
</tr>
<tr>
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<td>Adult female grizzly #28</td>
<td>4.7</td>
<td>0 100</td>
<td>25 75</td>
</tr>
<tr>
<td>30</td>
<td>Adult female grizzly #30.</td>
<td>5.3</td>
<td>0 100</td>
<td>39 61</td>
</tr>
<tr>
<td></td>
<td>May 26, 1997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Adult female grizzly #33.</td>
<td>3.7</td>
<td>0 100</td>
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<td></td>
<td>August 30, 2000</td>
<td></td>
<td></td>
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<td>Adult female grizzly #36.</td>
<td>3.7</td>
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<td></td>
<td>Female Mean ± 1 SD</td>
<td>4.2+0.8</td>
<td>0 100</td>
<td>14+17 86+17</td>
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<td></td>
<td>Total Mean ± 1 SD</td>
<td>4.6+0.8</td>
<td>0 100</td>
<td>23+19 77+19</td>
</tr>
</tbody>
</table>

¹ Deer based herbivore baseline. Deer hair δ¹⁵N mean ± 1 SD = 5.6 ±1.2 (n=15).
² Elk based herbivore baseline. Elk hair δ¹⁵N mean ± 1 SD = 3.6 ±1.2 (n=9).

The higher estimated mean meat percentage in the assimilated diet of male versus female grizzly bears when using the elk baseline is typical of interior grizzly bear populations. Although the baseline signatures of deer and elk differed, the isotope values indicate that this grizzly bear population depends on plant matter for the bulk of its nourishment. The low reproductive output of the population probably reflects this relatively low energy diet. The small number of grizzly bears sampled suggests caution with the results.

LITERATURE CITED
CHAPTER 9
HOME RANGE ANALYSIS
9. HOME RANGE ANALYSIS

Saundi Stevens and Michael Gibeau

We calculated multi-annual (1994-2002) home ranges for male and female grizzly bears by means of the 95% fixed kernel technique with a smoothing parameter using the Animal Movements extension in ArcView (Hooge and Eichenlaub, 1997). Home ranges were estimated using aerial telemetry locations. Aerial monitoring provides random and relatively unbiased location data. For bears with fewer than 30 aerial relocations, we supplemented the data set with ground telemetry relocations (maximum 1 location/day) (Tables 1 and 2). Home ranges were not estimated for bears with fewer than 30 aerial and ground relocations combined.

Radio collared grizzly bears were located on average, once per week weather permitting during their active season from den emergence to den entry. We generated 33 female grizzly bear home ranges (Figures 1, 2 and 3) and 16 male grizzly bear home ranges (Figures 4, 5 and 6). Female grizzly bears in the study area averaged a home range size of 520 km² (Table 9) and male home ranges averaged 1405 km² (Table 2).

We also identified 6 different jurisdictions across the region, each with different management objectives for grizzly bears. These included national parks, Alberta provincial lands, Alberta Kananaskis Country, Alberta provincial parks, British Columbia provincial parks and British Columbia provincial lands. We calculated the number of these jurisdictions that occurred in each grizzly bear home range and the mean number of jurisdictions for female and male home ranges.

Table 1. Multi-annual home range areas (km²) for female grizzly bears in the Bow River Watershed.

<table>
<thead>
<tr>
<th>FEMALE #</th>
<th>AREA (KM²)</th>
<th># OF GROUND LOCATIONS</th>
<th># OF AERIAL LOCATIONS</th>
<th>TOTAL # OF LOCATIONS ANALYZED</th>
<th># OF JURISDICTIONS HOME RANGE OCCUPIES</th>
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AVERAGE 521 1.7
Table 2. Multi-annual home range areas ($\text{km}^2$) for male grizzly bears in the Bow River Watershed.

<table>
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<th>MALE #</th>
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<th># OF GROUND LOCATIONS</th>
<th># OF AERIAL LOCATIONS</th>
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**DISCUSSION**

Male grizzly bear home ranges were on average 2.7 times larger than female home ranges in the Rocky Mountains of Alberta and British Columbia. This variation in home range size between sexes is typical of most grizzly bear populations and is largely influenced by the quality, quantity and distribution of available resources and the variability of human land use patterns (Berns et al. 1980, Knight 1980, Knight & Eberhardt 1984). Dahle and Swenson (2003) also speculate that an adult male grizzly bear will range further than a female to assess the territory for competitors, immigrants and potential mates for breeding season. The home range areas (Figures 1 through 6) we illustrate are minimal estimates, especially for bears whose range was calculated with few telemetry relocations. As the number of telemetry relocations increase, especially over multiple years, home range size will continue to increase to some extent.

The Central Rockies Ecosystem (CRE) is one of the most developed landscapes in the world where grizzly bears still survive (Gibeau 2000) and consequently, the larger the home range the greater the potential a bear is exposed to various human land uses and associated risk of mortality. Calculated survival rates may support this prediction of increased mortality risk relative to home range size. In the CRE where we document male grizzly bear home ranges to be larger than the females, it is also reported that adult male survival rates are lower (85%) than adult female survival rates (95%) (Garshelis et al. 2005).

The home ranges as illustrated in Figures 1 through 6 are theoretical probability maps based on telemetry data. Therefore, a mapped home range polygon overlaying a road, highway or townsite does not necessarily signify the bear crossed over or through that feature. For example in the Lake Louise area (Figure 2), female grizzly bears #30, #46 and #36 were never documented crossing the Trans Canada Highway (TCH) between 1994–2002, as their mapped home range polygons may suggest. Telemetry relocations show they have each been in close proximity to the highway and therefore the fixed kernel method for home range calculation estimates habitat across the TCH is within the probable estimate of a home range. Female grizzlies in the Banff area whose home range straddle the TCH (Figure 1) but haven’t actually crossed the TCH are #17, #32, and #40. Similarly, male grizzly #51 in the Lake Louise area (Figure 4) was never documented crossing to the south side of the TCH. We documented a larger percentage of male grizzly bears crossing the TCH than female grizzlies (Chruszcz et al. 2003). Chruszcz et al. (2003) explain that grizzly bears are reluctant to cross high-volume roads like the TCH and crossings are generally associated with movements into better habitat. Grizzly bears in the Kananaskis region (Figures 3 and 6) were documented crossing highway 40 frequently. This highway is unfenced with lower traffic volumes and therefore is more permeable to bears than the TCH. Although permeability for grizzly bears is greater on low-volume roads, mortality associated with vehicle collisions is still prevalent and should be mitigated (Chruszcz et al. 2003).
It is well documented that grizzly bears often move across several management or jurisdictional boundaries in the course of a year or their lifetime (Gibeau 2000, Raine and Riddell 1991, Mace and Waller 1997). We identified 52% of female home ranges and 75% of male home ranges occupied 2 or more different management jurisdictions within the CRE. Grizzly bears are wide ranging and occupy extensive home ranges to meet their habitat requirements; no single jurisdiction is likely to support a viable grizzly bear population in the long term. Integrated management between jurisdictions is essential (Herrero 1994).

Figure 1. Female Grizzly Bear Home Ranges, Banff Area
Figure 2. Female Grizzly Bear Home Ranges, Lake Louise Area
Figure 3. Female Grizzly Bear Home Ranges, Kananaskis Area
Figure 4. Male Grizzly Bear Home Ranges, Lake Louise Area.
Figure 5. Male Grizzly Bear Home Ranges, Banff Area
Figure 6. Male Grizzly Bear Home Ranges, Kananaskis Area
LITERATURE CITED
CHAPTER 10
RESOURCE SELECTION BY FEMALE GRIZZLY BEARS
10.1 CONTEXT TO RESOURCE SELECTION MODELS FOR FEMALE GRIZZLY BEARS IN THE EASTERN SLOPES BASED ON COARSE-FILTER AND FINE-FILTER APPROACHES

Jeannette Theberge and Saundi Stevens

INTRODUCTION

Understanding resource selection by animals is of considerable interest among ecologists, conservationists, and land managers because it can facilitate the conservation of resources and habitats used by a species, and thereby increase the likelihood of population persistence. For grizzly bears, survival and productivity of adult females are critical to population viability (Knight and Eberhardt 1985, Garshelis et al. In Press). Accordingly, detailed knowledge of the specific resource requirements of female grizzly bears is important for the management and conservation of the grizzly bear population in the eastern slopes of the Canadian Rocky Mountains in Alberta.

During the past decade advances have been made in statistics and geographic information systems (GIS) that have allowed the development of several techniques to describe resource selection. In the Alberta portion of the Central Rockies Ecosystem, resource selection by female grizzly bears has been investigated in 2 studies (Stevens 2002, Theberge 2002), each involving different methodological and management approaches. These studies respectively represent a coarse-filter and fine-filter approach to understanding adult female grizzly bear habitat selection. The different approaches lead to management implications at different scales.

This chapter provides an introductory context for the research conducted by Stevens and Theberge. The results of these studies are presented in the next 2 chapters. Details can be found in the original thesis (Stevens 2002) and dissertation (Theberge 2002). The final chapter of the Resource Selection Section of the Report highlights the major differences in the approaches and results of the two studies.

STUDY AREA

Both Theberge and Stevens studied the same 20,000 km² area east of the Continental Divide, focusing on bear home ranges in the Bow River watershed, an 11,400 km² area east of the Continental Divide (Figure 1). Stevens addressed an additional 5,000 km² area on the west side of the Continental Divide.

Home ranges were delineated for female grizzly bears, and resource selection functions (RSFs) were derived. Theberge used the software package KERNELHR to define home ranges at the 95% isopleth. Stevens used a 95% fixed kernel technique with a smoothing parameter using the Animal Movements extension in Arc View.

COARSE AND FINE APPROACHES

Selection refers to the disproportionate use of a resource compared to the availability of the resource (Manly et al. 1993). In Stevens (2002) and Theberge (2002), selection of resource features was determined by observing the ratio of features used by bears to their availability in the landscape. The statistical modeling of these ratios, or resource selection functions (Manly et al. 1993), identifies the combination of characteristics that provide the greatest likelihood of locating female grizzly bears.

Stevens (2002) investigated the correlation of female grizzly bear locations during the berry (summer/fall) season with the variables: greenness, and distance to greenness. She also investigated correlations of locations with density of high greenness, elevation and human access density in a 1.5-km radius moving window.
Theberge (2002) investigated the correlation of female bears with resource characteristics, during 2 seasons (spring through fall), and at several scales. At the 300-m diameter scale, she investigated vegetation type, proximity to vegetation edge, proximity to water, elevation, slope, and aspect. Also investigated were heterogeneous landscape patterns at the 300-m, 1.5-km, and 3.0-km diameter scales, specifically: vegetation diversity, vegetation dominance, terrain ruggedness, density of motorized access, and density of non-motorized access.

Human access density was incorporated differently in the 2 studies. Stevens investigated all human access in a 3.0-km diameter window. Theberge split this variable into non-motorized and motorized categories, measuring within 1.5-km and 3.0-km diameter windows.

Stevens’ approach to RSF modeling addressed coarse scales and is useful for identifying broad landscape changes for management. Theberge’s approach addressed multiple scales and is useful for identifying some habitat attributes that can be managed to enhance grizzly bear conservation.

LITERATURE CITED
10.2 GREENNESS AND SECURITY FOR FEMALE GRIZZLY BEARS: A COARSE-FILTER APPROACH TO MAPPING AND MANAGING BEAR HABITAT

Saundi Stevens

For more detailed information, please refer to the thesis “Landsat TM-based Greenness as Surrogate for Grizzly Bear Habitat Quality in the Central Rockies Ecosystem” at www.canadianrockies.net/Grizzly.

Maps depicting grizzly bear habitat quality are required to enable managers to efficiently identify important locations for bears. Because in some areas grizzly bears move among several jurisdictions that have inconsistent ecological mapping methods, generating a unified map has been problematic. Prior to this research, a validated habitat map for grizzly bears did not exist for the Central Canadian Rocky Mountains. “Greenness” is one variable biologists have identified from tassel-capped transformations of satellite images that has contributed to producing a GIS based cross-jurisdictional habitat map. The objective of my research was to determine the relationship between greenness values (a surrogate for habitat) and grizzly bear locations, then to develop a predictive habitat quality map, for the Central Canadian Rockies Ecosystem (CRE), according to empirically determined preferences for high greenness values. I then used the habitat quality map in conjunction with the security model to identify areas of high quality habitat that are, or could be managed for grizzly bear security. I identified the percent of available land base that is secure high habitat quality at various landscape levels and concluded that the percentage of land base in secure high quality habitat is small across the CRE; currently no jurisdiction, BMU or female grizzly bear home range meets USDA Forest Service targets for providing habitat security for long term grizzly bear conservation. I identified specific applications of the secure habitat quality model in grizzly bear conservation and management strategies. The predictive models of habitat quality and security areas in the CRE are necessary tools to assist managers in cross-jurisdictional planning and demarcation of important sites for grizzly bears.

I incorporated data from the Eastern Slopes Grizzly Bear Project and the Upper Columbia Bear Research Project; each encompasses separate, biologically distinct study areas within the CRE. I used a seamless vegetation greenness map generated by Wierzchowski (2000) for the CRE. Seasonal analysis for selection of greenness by grizzly bears was not possible because of limited availability of cloud-free satellite images during springtime (June – mid July). Greenness modeling depends upon good quality cloud free Landsat satellite images. Complete data were available for the berry season (mid July – end of October) and therefore my analyses were restricted to that period.

As a surrogate for land cover type (habitat), I analyzed greenness scores and two variables derived from the greenness model; distance to high greenness and density of high greenness. I also included the variables elevation and human access density to develop a probability of occurrence model and habitat quality map for grizzly bears. I identified differences in use of pseudo-habitat variables between male and female, wary and habituated grizzly bears in both study areas. Adult female grizzly bears were the focus of my habitat modeling as they are the reproductive engines of a population and their success is fundamental to sustaining populations for the long term (Mattson 1993, Mace et al. 1999, Gibeau 2000).

I used resource selection analysis that compares ‘used’ versus ‘available’ (random) points to determine probabilities of resource selection based on what is available (Manly et al. 1993, Garshelis 2000). I evaluated 2nd order resource selection for female grizzly bears in each study area, defined by the outermost boundary of the compilation of all female home ranges. I developed a set of candidate models, per study area, of all likely variable combinations that may influence the probability of occurrence of female grizzly bears. I used logistic regression to estimate parameter coefficients and likelihood values for each candidate model and compared them using the Akaike Information Criteria (AIC) (Burnham and Anderson 1998). In both study areas, density of high greenness and distance to high greenness were the most important and strong predictors for female grizzly bear occurrence.
I used coefficients from the top AIC model in both study areas to generate a map of relative probability of female grizzly bear occurrence throughout the CRE, then categorized the probability values into 3 equal intervals to delineate low, moderate or high habitat quality (Figure 1).

![Map of relative probability of female grizzly bear occurrence throughout the Central Rockies Ecosystem, categorized by 3 equal intervals of low, moderate or high habitat quality.](image)

Figure 1. Map of relative probability of female grizzly bear occurrence throughout the Central Rockies Ecosystem, categorized by 3 equal intervals of low, moderate or high habitat quality.

I updated the secure area model developed by Gibeau et al. (2001) for female grizzly bears using the most recent and accurate spatial data for motorized and non-motorized access across all jurisdictions in the CRE (Figure 2). I then combined the security area analysis with the habitat quality map and identified areas of secure high quality habitat (Figure 3). I defined the percent of available land base that is secure and of high habitat quality across 4 major jurisdictions within the CRE, across individual BMU’s within National Parks and Kananaskis Country, Alberta and within individual female grizzly bear home ranges. My results (Stevens 2002) indicate no jurisdictions in the CRE meet the USDA Forest Service target level of 68% secure habitat (IGBC 1998). A small proportion of each jurisdiction encompasses secure high quality habitat. British Columbia provincial lands have the largest percentage (13%) of their available land base in secure high quality habitat. The National Parks have the least amount of available land base in secure high quality habitat (5%).
There is strong support for preserving areas where grizzly bears will be secure from encounters with humans as these would foster the wary behavior in bears that most managers consider to be desirable (Mattson 1993, Mace and Waller 1997, Gibeau et al. 2001). These secure areas are also expected to provide enough forage so bears can meet their energetic requirements, while at the same time choosing to avoid people (Mattson 1993). Combining the security area model with knowledge of habitat quality is essential to highlight areas most productive for grizzly bears. Secure high quality habitat will most reliably maintain fitness or survival of individual grizzly bears and it will foster reproductive potential of adult females, important to the viability of the population.

The secure habitat quality map offers recent scientific data on habitat (established by the probability of bear occurrence based on greenness) and human activities influencing grizzly bears. It can help identify specific areas within the CRE that should receive special management attention specifically during the summer and fall season and is a tool that may contribute significantly to various cross-jurisdictional management and conservation initiatives.

Figure 2. Update of the secure area model developed by Gibeau et al. (2001) for female grizzly bears using the most recent and accurate spatial data for motorized and non-motorized access across all jurisdictions in the CRE.
Figure 3. Areas of secure high quality habitat for grizzly bears, displayed by combining the habitat quality map with the results from security area analysis.

The strength in this model is that variables derived from greenness are strong predictors of grizzly bear occurrence. Satellite images are attainable for any region or landscape and with professional GIS technical support are easily transformed into greenness bands. Some management applications may experience a limitation to using greenness as a pseudo-habitat variable because the relationships between greenness values and vegetative community types are yet unknown. Vegetation type is undeterminable from the model and therefore managing for certain habitat enhancement projects, for example, cannot be done without more site-specific investigation.

Because greenness is relatively easy to measure, this analysis provides a good coarse-filter tool for management to assess changes in grizzly bear habitat across time and over large landscapes, particularly during the summer/fall season. If, over time, it appears that greenness levels are changing, especially within secure areas, then management action may be necessary to avoid a decline in habitat effectiveness, such as enhancing habitat attributes delineated in a fine-filter approach (see next chapter). This map will not only help management and conservation programs in the CRE to prevent further loss of existing secure high quality habitats, but also to guide them in identifying areas for enhancing bear habitat quality and increasing habitat effectiveness through restoration of secure areas.
LITERATURE CITED
ABSTRACT
Although research suggests that many species perceive multiple scales, few studies have included a range of scale-dependent variables in studies regarding resource selection. We investigate the selection of such features for grizzly bears - a mobile species whose landscape selection could be influenced by landscape pattern. We investigate whether female grizzly bears in the eastern slopes region of the Alberta portion of the Central Rockies Ecosystem select resource characteristics and heterogeneous landscape patterns differently than available within home ranges when landscape patterns are measured at multiple scales simultaneously. Resource characteristics were measured in the 300-m diameter immediate vicinity of bears, specifically vegetation, slope, aspect, elevation, proximity to edge, proximity to water, and proximity to human activity. Heterogeneous landscape patterns were measured in 300-m, 1.5-km, 3.0-km diameter windows, specifically vegetation diversity, vegetation dominance, terrain ruggedness, density of motorized access, and density of non-motorized access. We used logistic regression to calculate resource selection functions. Female grizzly bears responded to environmental conditions beyond the immediate vicinity of 300 metres, frequently selecting heterogeneous landscape patterns at different scales, and simultaneously at several scales. We describe results for wary individuals during 2 seasons. All female bears selected pockets of low-density non-motorized access by humans at the 1.5-km scale, within larger 3.0-km areas of high-density non-motorized access by humans. For all female bears, relatively high diversity of vegetation types was selected at the 300-m scale in the preberry season, and selection for high diversity at the 1.5-km scale in the berry season. Homogeneous vegetation within the 300-m scale was never selected. Close proximity to edge was consistently selected. Wary females selected high levels of ruggedness at the broadest scales during both seasons. Also commonly selected were general-shrub, graminoid meadows, and avalanche paths, suggesting their general importance to female grizzlies. We recommend that resource selection studies incorporate variables at multiple scales.

Management along the eastern slopes should maintain vegetation edge and diversity of vegetation communities through the maintenance of disturbance regimes. Furthermore, management should attempt to minimize human disturbance in areas that have any or all of the following characteristics: are within 60 metres of vegetation edges, have high levels of vegetation diversity within 300-m and 1.5-km windows, consist of rugged terrain within broad 3.0-km areas, contain graminoid meadows and avalanche paths, or are close to riparian areas. To take into account habitat selected by grizzly bears levels of human access should be minimal in contiguous 1.5-km diameter areas that contain these habitat attributes. We recognize that competing land use pressures will often exist.

In applying seasonal resource selection functions to the eastern slopes landscape, we identified 4 geographic areas containing a concentration of high probability of adult female occurrence. These areas were: 1) around Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area, south to and including the Burnt Timber drainage, 3) around Banff townsite, and 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. We also identified numerous smaller pockets of high probability of female grizzly occurrence distributed throughout the study area but especially south of the Trans Canada Highway. Each of the 4 areas with a concentration of high probability of adult female use is a candidate for management that will allow for grizzly bear habitat use with minimal human-caused mortality risk. This will be challenging because of extensive human use in these areas.

INTRODUCTION
There is increasing interest and attention to the possibility that many species select resources at multiple scales (Senft et al. 1987, Otis 1998). Several studies have described the influence of scale upon resource selection for species of mammals, birds, and insects (With 1994, Wallace et al. 1995, Meyer et al. 1998, Clark et al. 1999, Naugle et al. 1999, Kerkhoff et al. 2000, Apps et al. 2001). However, most studies of grizzly bear ecology have investigated habitat use by describing attributes in the immediate environment.
Proximity and juxtaposition of various landscape or resource characteristics also influence the distribution of individuals within a species (Milne et al. 1989, Dunning et al. 1992). Landscape pattern has not been frequently considered in wildlife studies (Otis 1998). The movements of a highly mobile species such as the grizzly bear might be influenced by the pattern of landscape attributes at different scales. Landscape pattern can be described by measuring the level of heterogeneity of various features (O’Neill et al. 1988). Because a landscape may appear homogeneous at one scale but heterogeneous at another (Musick and Grover 1991), the measurement of heterogeneity is dependent on spatial scale. Analysis of historical sightings of grizzly bears in Washington suggested that bears selected vegetation diversity within areas that were 550-m diameter (Agee et al. 1989). Otherwise, the selection of heterogeneous landscape patterns at various scales beyond the immediate vicinity of individual grizzly bears has not been thoroughly investigated.

Understanding resource selection by grizzly bears is one important component of management to ensure population persistence. In the eastern slopes of the Canadian Rocky Mountains in Alberta, as in other ecosystems, the survivorship and productivity of adult female grizzly bears are critical to population viability (Knight and Eberhardt 1985, Garshelis et al. 2005). Consequently, detailed knowledge of multi-scale resource requirements of female grizzlies might aid conservation of the species. In this paper, we investigate whether female grizzly bears in the eastern slopes region select resource characteristics and heterogeneous landscape patterns differently than available within home ranges when landscape patterns are measured at multiple scales simultaneously. The resource characteristics we measured were: vegetation, slope, aspect, elevation, proximity to edge, proximity to water, and proximity to human activity. Each of these variables was measured within a 300-m diameter window of bear and random locations. We defined landscape patterns as the level of vegetation diversity, vegetation dominance, terrain ruggedness, density of motorized access by humans, and density of non-motorized access by humans, measured at 3 scales (in 300-m, 1.5-km, 3.0-km diameter windows around bear and random locations).

This multiscale investigation provides information for land managers using a fine-filter approach. To support conservation of female grizzly bears, managers can preserve or manipulate the variables with which bear locations are correlated. In contrast, coarse-filter approaches would involve the management of variables that are correlated with bear range across large regions.

**STUDY AREA**

We conducted this research along the eastern slopes of the Alberta portion of the Central Rockies Ecosystem. This is part of the Continental Ranges of the Southern Rocky Mountains, part of the Eastern System of the Canadian Cordilleran region, located approximately 100 km west of Calgary, Alberta (Bostock 1970) (Figure 1). The study area was approximately 22,000 km², defined by the outermost movements of radio-collared grizzlies. In this chapter, we focus on adult females whose home ranges were located within the 11,400 km² area of the Bow River watershed (Gibeau and Herrero 2001) (Figure 1). Analysis was conducted within the home ranges of radio-collared females (Figure 2). Gibeau (2000) presents additional details regarding the Bow River watershed. Based on expected ecological similarity results were extrapolated to the larger 22,000 km² study area.
Figure 1. Study area, specifically the Bow Valley Watershed, and the surrounding region during 1994 to 1999. Human activity is illustrated by major transportation routes only.

Figure 2. Composite home ranges, pooled across seasons and years, for individual female grizzly bears investigated in the study area from 1994 to 1999 (Theberge 2002).
METHODS
Telemetry and Data Collection

Grizzly bears were captured and radio collared in the study area between 1994 and 1999 (Stevens et al. 1999). Individuals were equipped with either a conventional VHF radio collar or ear tag transmitter. We only included aerial locations in the analysis to ensure that the spatial relationship between relocations was not influenced by limitations in access through mountainous terrain by observers. Aerial relocations were acquired (using the methods of Mech 1983) every 1 to 2 weeks during the daylight hours. Accuracy of air telemetry was estimated to be within 150 metres and was determined by testing with radio collars placed in known locations (Gibeau 2000). We assumed the aerial relocations were independent, and we screened them to ensure that locations were more than 24 hours apart. It is likely that an adult female grizzly bear can cross its home range in less than 24 hours (personal observation), and consequently has access to any location in its home range in that time frame. In later sections, we refer to relocations as bear locations or used locations.

The individuals included in this study were 14 adult female grizzly bears that were of reproductive age (> 6 years old) and that exhibited wary behaviour towards humans. Also investigated in the study, but not reported here, was resource selection of females with cubs-of-the-year and habituated female bears (Theberge 2002).

We classified individual bears into 2 behavioural approaches towards humans, wary and habituated, based on field observations (described in Gibeau 2000). Individual bears that exhibited tolerance towards humans were considered to be habituated (Mattson et al. 1992). For example, some habituated individuals in the eastern slopes study area approached people, used areas close to roads, and crossed highways more than wary individuals (Mueller 2001). Theberge (2002) analyzed habituated female bears separately from wary females to account for potentially different resource selection characteristics of each group, particularly in response to variables related to human presence. We assume that most jurisdictions prefer to manage landscapes to encourage survivorship of wary bears.

Female grizzlies used in this study were followed using telemetry relocations for 4 to 6 years. We pooled data for individual bears across years to maximize sample size, and stratified by 2 seasons.

We identified 2 seasons. The "preberry season" extended from den emergence, approximately the 1st of May, to 15th of July. We named the second season the "berry season", referring specifically to the summer during which many berry species were ripe, through to the late fall when berries were no longer available. The commencement of the "berry season" coincided with the emergence of buffaloberry (Shepherdia canadensis) generally around the 16th of July, and extended until after the buffaloberrries were no longer available and the bears re-entered the dens around approximately the 31st of October (as is consistent with other research in this study area - Gibeau 2000, Mueller 2001). We identified these seasons to facilitate analysis of resource selection across time, because season had a significant effect on habitat selection in other studies (McLellan and Hovey 2001).

We estimated home ranges for each bear for each season using the 95% fixed kernel algorithm available in the software program KernelHR (Seaman et al. 1998).

To facilitate estimation of a resource selection function (RSF), we generated approximately 3,000 random locations inside each seasonal home range for each bear. Collectively, these random locations represent the relative availability of resource characteristics within the home ranges. In later sections, we refer to these randomly chosen locations as available locations.

Resource and Landscape Characteristics

We extracted resource characteristics for bear locations and random locations from digital data layers using a Geographic Information System (GIS) within the seasonal home ranges of each bear. Unless otherwise noted, all digital data layers were in raster format with 30-metre pixel resolution. For spatial analysis, we used the following software: MapInfo version 4.5 (MapInfo Corporation 1997), ArcView version 3.1 (ESRI 1998), and IDRISI 32 (Clark Labs 1999).

We measured 2 types of resource and landscape characteristics, and called them "immediate-variables" and "heterogeneity-variables". Immediate-variables were measured within an area 300-m in diameter surrounding bear and random locations, and included the variables slope, elevation, aspect, and vegetation type. The immediate-variables also included distance measures such as proximity to edge, proximity to water, and proximity to human access. Heterogeneity-variables described landscape patterns at 3 scales,
specifically 300-m, 1.5-km, and 3.0-km diameters, and included density of motorized human access, density of non-motorized human access, vegetation diversity, vegetation dominance, and ruggedness. These heterogeneity-variables are scale-dependent. Scale is defined as a combination of grain, specifically the resolution of the data, and extent, specifically the dimensions of the study area (Turner et al. 1989). We investigated 3 scales (3.0-km, 1.5-km, and 300-m diameter) by holding the extent constant and changing the resolution. The broad 3.0-km scale reflects the average daily movement of adult female grizzly bears, which in the eastern slopes region is approximately 3.4 km covering an area of 9.0 km² (Hamer and Herrero 1983, Gibeau et al. 2001).

**Immediate-Variables**

Slope, elevation, and aspect of each random and bear location were extracted from a digital elevation model (Wierzchowski 2000) with a 30-metre resolution. For slope and elevation, we accounted for telemetry error by averaging the slope and elevation over an area 150-metres in radius (70,686 m²). Averaging was conducted using a moving window routine in a raster-based GIS. We recorded slope in degrees, later dividing by 10 so that the odds ratios for the RSF could be interpreted as changes in probability in bear use given a change in slope of 10 degrees. We recorded elevation in metres, later dividing by 100 so that the odds ratios from the RSF could be interpreted as changes in probability of bear use given a change in elevation of 100 metres. We divided aspect into 5 classes (NE-facing, NW-facing, SE-facing, SW-facing, and flat). We accounted for telemetry error using a 300-metre diameter moving window routine where the dominant aspect type, the modal class, was assigned to each 30-metre pixel in the image.

Vegetation characteristics associated with each random and bear location were determined from a land cover layer derived from Landsat Thematic Mapper (TM) images taken in August 1995 and 1998 (Wierzchowski 2000). Originally, the land cover layer contained the following 7 classes: water, ice/snow, rock/soil, deciduous forest, graminoid, shrub, and conifer. Subsequently, we subdivided the latter 3 classes relative to their abiotic attributes (details provided below), resulting in the following classes: graminoid, steep-slope-avalanche-mix, general-shrub, shrub-SW-facing, general-conifer, and conifer-SW-facing. Consequently, our analysis examined 10 vegetation classes, also referred to as vegetation types. This subdivision made the classes more sensitive to understory vegetation that might be used by grizzly bears. We accounted for telemetry error using a 300-metre diameter moving window routine in which the dominant habitat type, the modal class, was assigned to each 30-metre pixel in the image (Mace et al. 1996).

Steep-slope-avalanche-mix (hereafter called avalanche) referred to areas with steep slopes (>30 degrees), high elevation (>2300 metres), and high level of greenness reflectance (>35 raw score) in which the dominant vegetation type was graminoid meadows or shrub. Approximately 5% of this vegetation type classified in this manner also contained conifer trees. Nearly 40% of this vegetation type contained avalanche paths, but sometimes they also contained grass-shrub-conifer vegetation types that were in areas of high relief that have a strong likelihood of producing avalanches.

The conifer and shrub classes were subdivided by aspect and slope to delineate those vegetation types on south-west facing slopes with dry slopes where the production of grizzly bear foods might be substantial. In conifer forests, primary grizzly bear foods were buffalo berry, bearberry (Arctostaphylos uva-ursi), grass species, and ant larvae. In shrub fields, primary grizzly bear foods were buffalo berry, yellow hedsarum (Hedysarum sulphurens), pink hedsarum (H. alpinum) and ant larvae (Hamer and Herrero 1983). Of specific interest were areas that faced 180-270° azimuth with slopes greater than 3 degrees. We subdivided the conifer and shrub classes by these slope and aspect criteria, and called the resulting classes shrub-SW-facing and conifer-SW-facing. Conifer forests on non-SW-facing slopes, including flat areas, were termed general-conifer. Similarly, shrub fields on non-SW-facing slopes, including flat areas, were termed general-shrub. In the analysis of the resource selection functions, we described bear use of classes within the categorical variables, specifically aspect and vegetation, relative to bear use of a "reference-category". We chose general-conifer as the reference-category for vegetation due to neutral selection of this vegetation type by the female grizzlies. We chose flat as the reference-category for aspect to facilitate comparison with other aspect classes.

The hydrology layer contained information from digital data, at 1:50,000 scale, from the National Topographic System (see http://maps.nrcan.gc.ca/topographic.html), and base data from the Province of Alberta. The digital human use layer, at the 1:50,000 scale, contained vector, point, and polygon data of
motorized roads, trails and human facilities. The human use layer was created in 1998 and subsequently updated (Gibeau 2000). Both the vector hydrology and human use layers were rasterized at 30 metre resolution.

Several proximity measures were calculated for each bear and random location by measuring the straight-line distance (in metres) to the closest attribute, specifically distance to edge, water, and human access. Although the distances were measured in metres, we divided the data by 100 so that the odds ratios for the RSF could be interpreted as changes in probability of bear use given a change in distance of 100 metres. Edge referred to any boundary between vegetation types identified in the land cover layer. Water referred to permanent water bodies such as lakes, rivers and streams. Human access referred to linear features and nodes of human use, including the Trans-Canada Highway, railway, paved and unpaved roads, high and low use trails, and campgrounds.

**Heterogeneity-Variables**

Density of human access (km/km²) was described for 2 types of human use, specifically motorized access and non-motorized access. Motorized access included roads capable of being driven on and railways. Non-motorized access included hiking trails. For both types of human activity, densities were measured within the home ranges in both 1.5-km diameter (1,767,146 m²) and 3.0-km diameter (7,068,584 m²) moving window routines.

Pattern of vegetation types was described using diversity and dominance indices (Turner et al. 1989) at 3 scales using moving window routines at 300-metre diameter, 1.5-km diameter, and a 3.0-km diameter. Diversity of vegetation types was calculated using the following equation:

\[ H = -\sum_{k=1}^{s} (P_k)\ln(P_k) \]

where \( P_k \) is the proportion of the kernel in vegetation type \( k \), and \( s \) is the number of vegetation types observed (Turner 1989). Dominance measures the extent to which one or a few vegetation types dominate within 300-m, 1.5-km and 3.0-km analysis-windows,

\[ D_o = H_{\text{max}} + \sum_{k=1}^{s} (P_k)\ln(P_k) \]

where \( s \) is the number of vegetation types observed, \( P_k \) is the proportion vegetation type \( k \) in a given kernel, and \( H_{\text{max}} \) is ln(\( s \)) which is the maximum diversity when vegetation types occur in equal proportions (Turner 1989). We measured both diversity and dominance of vegetation types to aid in interpretation of the degree of heterogeneity that existed in analysis-windows. For example, areas with several vegetation types in relatively equal proportion to each other would be characterized by positive selection of diversity, and negative selection or non-significance of dominance. Conversely, if both diversity and dominance were positively selected, then one or two vegetation types dominated in area over the several other types present.

Variability in topography was described using a ruggedness index at 3 scales using moving window routines at 300-m, 1.5-km, and 3.0-km diameters. Ruggedness was calculated using the following equation:

\[ TR = ((CDr)\times(ARr)) / ((CDr)+(ARr)) \]

where CD is the density of contour lines within a given kernel, AV is the variability of eight cardinal aspects within a given kernel, and \( r \) is the kernel size (300-m, 1.5-km, or 3.0-km diameter moving window) (Nellemann and Thomsen 1994, Gibeau 2000, Clevenger et al. 2002). Contour lines and aspects were obtained from a digital elevation model (Wierzchowski 2000) with a 30-m pixel resolution.

**Building RSF Models**

We utilized logistic regression to compare used and available resource characteristics, for wary and habituated bears during the 2 seasons. Multi-scale models were created for wary bears in the preberry and berry seasons.

We used logistic regression to differentiate used (telemetry) and available (random) resources in individual home ranges (Thomas and Taylor 1990, described as 'design III' in Manly et al. 1993) to model the
relative probabilities of occurrence for adult female grizzly bears as a function of the combination of variables measured (Manly et al. 1993, Mace et al. 1996, Mace et al. 1999). Resource selection functions (RSFs) were defined as having the following form (see equation 8.7 from Manly et al. 1993: page 127):

$$w(x) = \exp (\beta_1 x_1 + \ldots \beta_p x_p)$$

where \(w(x)\) is the RSF and \(\beta_1 x_1 + \ldots \beta_p x_p\) is the linear combination of characteristics of the available resource units. We used backward stepwise elimination, thereby removing variables when \(p > 0.05\). We screened pairs of continuous variables for multicollinearity using the Spearman rank correlation coefficient. We removed one variable of a correlated pair if correlations were greater than 0.80. Correlations between 0.50 and 0.80 were investigated for domination of one variable over the other. If domination occurred, one variable of the pair was removed. We considered final models with \(p \leq 0.05\) to be significant. We considered individual variables to be significant in the model when \(p \leq 0.05\). Relative probabilities of bear occurrence were spatially displayed using ArcView 3.1.

**Interpretation of Results**

The odds ratio (\(\exp(\beta)\)) describes the relative probability of being in one group divided by the relative probability of being in the other group (the groups being bear or random location) (Manly et al. 1993, Tabachnick and Fidell 1996). The odds ratio is the increase (or decrease) in the odds of being in one outcome category given an increase in the value of the predictor by one unit (Tabachnick and Fidell 1996). For distance measures, we interpreted the odds ratio as the relative probability that a bear would use a location that is further away from a habitat attribute, such as a vegetation edge, given that 2 locations had identical habitat attributes except that one was further away than the other from the habitat attribute to which distances were measured. Similarly, for categorical variables, the odds ratio for each category is compared to reference-category (general-conifer and flat). For example, the odds ratio would express the relative probability that a bear would use a specific vegetation type in reference to the general-conifer reference-category. The direction of the relationship of the odds ratio was expressed as negative or positive. For heterogeneity indices, specifically diversity, dominance and ruggedness, we described the odds ratio only in the direction of the relationship, because it is difficult to interpret the increase of an index by one unit. Comparisons for odds ratios could only be made between the main effects for variables if the unit of measurement was the same (e.g. distance in metres, or ruggedness). However, for categorical variables (e.g. aspect and vegetation) comparisons could be made between sub-categories.

We also expressed the odds ratio in terms of percent change in the likelihood of selection. The "selection strength" of each variable is the percent change in the relative likelihood of selection given one unit of increase for continuous variables, or given the presence of a category compared to the reference-category. We excluded the following variables from analysis due to domination or multicollinearity: dominance (3.0-km and 1.5-km scales), ruggedness (1.5-km scale), density of non-motorized access (1.5-km scale), and proximity to humans.

To graphically illustrate the distribution of relative RSF values across the study area, the variable coefficients were applied to digital layers of the study area. Relative RSF values were transformed using natural logarithms, and classes of relative probability of bear occurrence were created based on standard deviations from the mean logarithmic relative RSF value.

**RESULTS**

Models in both seasons were significant (Preberry season: \(-2LL=3911.4, \chi^2 = 878.5, df=20, p<0.001, N_{used}=396, N_{available}= 42652\); Berry season: \(-2LL=3913.4, \chi^2 = 1791.5, df=16, p<0.001, N_{used}=410, N_{available}= 39459\)). Detailed results are described in Theberge (2002, page 133, Table 4-7).

Resource selection is summarized to aid visual comparison between models at each scale (Figure 3). Selection or avoidance of categorical variables, vegetation and aspect, are in reference to the general-conifer and flat classes, respectively. Most of the heterogeneity-variables were selected by female grizzly bears. Several immediate-variables were selected.

Of the heterogeneity-variables in the preberry season, those at the 3.0-km scale dominated, with strong significance for ruggedness and density of non-motorized access (\(p<0.0001\), and negative significance
(avoidance) for density of motorized access (p=0.0001). Diversity at 3.0-km was also negatively significant (p=0.0160). Density of non-motorized access was negatively selected (avoided) at the 1.5-km scale (p<0.0001). Few heterogeneity-variables were significant at smaller scales.

<table>
<thead>
<tr>
<th>Heterogeneity Variables</th>
<th>Immediate Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruggedness</td>
<td>Vegetation</td>
</tr>
<tr>
<td>Diversity</td>
<td>General-Shrub</td>
</tr>
<tr>
<td>Dominance</td>
<td>Deciduous</td>
</tr>
<tr>
<td>Density non-motor</td>
<td>Graminoid</td>
</tr>
<tr>
<td>Density motor</td>
<td>Avalanche</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Ice/snow</td>
</tr>
<tr>
<td></td>
<td>Rock/soil</td>
</tr>
<tr>
<td></td>
<td>Conifer SW facing</td>
</tr>
<tr>
<td></td>
<td>Shrub SW facing</td>
</tr>
</tbody>
</table>

Legend:
- ■ = Significant (+)
- □ = Significant (-)
- □ = Not Significant

![Table of heterogeneity variables](image)

Figure 3. Comparative illustration of results from two seasonal multi-scale models investigating resource selection for wary female grizzly bears. Within each row of squares, each square represents the relationship of a variable to a specific seasonal model (see legend). Specifically, individual squares represent wary bears in the preberry season, and wary bears in the berry season. Significance was p < 0.05. Additional details are provided in original dissertation (Theberge 2002, page 133).

During the berry season, wary bears selected many of the same heterogeneity-variables at the 3.0-km scale as in the preberry season. Compared to the preberry season at the 3.0-km scale, significance was comparably strong for both density of non-motorized access and motorized access (p<0.0001), but weaker for ruggedness (p=0.0208). At the 1.5-km scale, bears selected density of non-motorized access with strong significance (p<0.0001), and diversity with less significance (p=0.0249). Heterogeneity-variables were not selected at the 300-m scale. Dominance was not selected in either season. Relative probabilities of occurrence by adult female grizzly bears across the study area (Figures 4 and 5) illustrate that valley sides, valley bottoms, and especially valley bottom confluences, were likely to be used frequently. These areas tended to have relatively open montane or sub-alpine vegetation where human activity, such as trail or road building, has opened the tree canopy. Within these areas are pockets of higher probability of female grizzly occurrence. The spatial distribution of areas with the highest probability of occurrence varies between the two seasons but is somewhat similar (e.g. see inset of Figures 4 and 5).

Geographically defined areas that had a concentration of high probability of female grizzly occurrence were: 1) around Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area, south to and including the Burnt Timber drainage, 3) around Banff townsite, and 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. Also numerous smaller pockets of high probability of female grizzly occurrence were distributed throughout the study area but especially south of the Trans Canada Highway.
Figure 4. Relative probability of occurrence of adult female grizzly bears in the preberry season during 1994 to 1999 in the eastern slopes of the Canadian Rocky Mountains. Based on resource selection functions from Theberge (2002).
Figure 5. Relative probability of occurrence of adult female grizzly bears in the berry season during 1994 to 1999 in the eastern slopes of the Canadian Rocky Mountains. Based on resource selection functions from Theberge (2002).
DISCUSSION

We conclude that female grizzly bears used resource characteristics and heterogeneous landscape patterns differently than available within their home ranges when landscape pattern was measured at multiple scales. We showed that within individual home ranges there was selection by female grizzly bears for environmental characteristics beyond the immediate vicinity of 300 metres. Bears responded to, and often select for or against heterogeneous landscape patterns at different scales and simultaneously at several scales. These results are discussed below.

Selection by Bear Groups

The greatest likelihood of female grizzly bear occurrence, by season, was typified by the following characteristics.

1. Wary females in the preberry season: At the broad 3.0-km scale, females selected areas of low diversity of vegetation types, high ruggedness of terrain, low motorized access density, and moderately high non-motorized access density. At the 1.5-km scale selected was low density of non-motorized access. Within these broader landscapes, selected at the 300-m scale were high vegetation diversity, close proximity to edge, graminoid meadows, avalanche paths, and flat aspects. Rock was avoided.

2. Wary females in the berry season: At the broad 3.0-km scale, females selected high ruggedness, low density of motorized access, and moderately high density of non-motorized access. At the 1.5-km scale bears selected low density of non-motorized access, and high vegetation diversity. Within these broader landscapes, selected at the 300-m scale were graminoid meadows, close proximity to edge, and close proximity to water. Rock was avoided.

Characteristics of Responses to Human Access

In the multi-scale models, all female bears consistently selected pockets of low non-motorized human access density (1.5-km scale) within larger areas (3.0-km scale) of higher levels of non-motorized human access density. The apparent attraction at the 3.0-km scale can be explained because frequency of non-motorized human access, such as hiking trails, is common in the region and may be located in potentially productive areas that would be used by grizzly bears. In this study area, the high amounts of rock and ice, and associated highly rugged terrain, compresses usable habitat into valley sides and bottoms that are vegetated. Because hiking trails are also in these vegetated areas, it is possible that most bears cannot avoid being within 3.0 km of trails in vegetated areas. Donelon (2004) found that grizzly bears near Canmore, Alberta used areas closer to trails more than expected during the berry season.

Dense areas of motorized human access were never positively selected by female grizzly bears. Similarly, Gibeau (2000) documented different levels of access density, when motorized and non-motorized densities were combined, surrounding the locations of wary and habituated individuals in the eastern slopes region. Other research indicates that grizzly bear presence is negatively correlated with increasing density of high-use roads (Mace et al. 1996, Mace et al. 1999, Gibeau 2000).

Grizzly bears can persist in areas with roads and other human activities (McLellan and Shackleton 1988, Mace et al. 1996). However, Boone and Hunter (1996) illustrated, through computer simulation in a Montana-based model, that construction of permanent roads could cause great change to grizzly bear movements. Gibeau et al. (2002) found that adult female grizzly bears in the eastern slopes region of the Central Rockies Ecosystem may be choosing to avoid humans instead of seeking out high quality habitats. In accordance with Gibeau et al. (2002), our results indicate that human-specific variables were some of the most dominant variables in many models, illustrated by relatively small p-values. In support of the claim by Gibeau et al. (2002), our results indicate that the greatest likelihood of bear presence, particularly for wary bears, is in areas with a combination of selected ecological variables in 1.5-km diameter pockets of low densities of non-motorized access by humans.

Because the locations of the bears were restricted to daylight hours, our research does not address grizzly bear proximity to human activity or access density during the night. In the eastern slopes region, grizzly bears were closer to trails during periods when humans were inactive, between 17:00-08:00 hours (Gibeau et al. 2002). Due to aerial telemetry constraints the telemetry locations that we used in this study primarily represented daylight hours. Donelon (2004), using GPS telemetry collars on grizzly bears, showed that
grizzly bears near Canmore and Lake Louise, Alberta, avoided areas of high human use during daylight hours but used the same areas more than expected at night when human use was low.

**Characteristics of Vegetation Pattern**

The mosaic of vegetation on the landscape in the eastern slopes region can be described by diversity, dominance, and distance to vegetation edges. To aid interpretation of the trends in the results, we discuss these variables together in this section.

Presence of female grizzly bears was frequently correlated with vegetation diversity at several scales. Wary female bears did not select areas of homogeneous vegetation, specifically they did not select low diversity with high dominance. Diversity might be important to grizzly bears due to increased variety in forage types, increased access to vegetation edges, and increased productivity of bear foods. Conversely, diversity of vegetation types might increase search time for forage, as a bear is required to search through a variable environment.

The models suggest 2 seasonal trends - selection for high vegetation diversity at the 300-m scale in the preberry season, and selection for high diversity at the 1.5-km scale in the berry season. Selection for high diversity at the fine scale during the spring might reflect the phenology of plants that are foods for grizzly bears. In the eastern slopes region, the succession of plant consumption by grizzly bears in the spring changes from hedysarum (*Hedysarum sulphureascens* and *H. alpinum*) roots, to horsetails (*Equisetum arvense*), grass species, and cow parsnip (*Heracleum lanatum*) (Hamer and Herrero 1987a). In a mountainous environment, such as the eastern slopes region, it is possible that the presence of microclimates from topographic change create local variability in plant maturity, thereby creating a shifting mosaic of useable habitats for grizzlies in the spring. This is consistent with phenologically driven feeding micro-habitat shifts previously observed in a portion of the study area (Hamer and Herrero 1987a).

That wary females in the preberry season select low diversity at 3.0-km and high diversity at 300-m suggests that these individuals can find fine-scale ecological attributes amongst broad areas of low diversity. This ability has also been suggested in other studies by observations in which grizzly bears have consistently foraged in small microsites dense with bear foods (Hamer and Herrero 1983, Waller and Mace 1997).

The second trend, during the berry season when wary bears selected areas with high diversity at the 1.5-km scale, potentially reflects selection for general proximity of a variety of vegetation types. Due to the broadspread presence of ripe buffaloberry (*Shepherdia canadensis*), bears might not have selected high levels of vegetation diversity at the local 300-m scale.

There is limited literature with which to compare the selection of heterogeneous vegetation patterns, specifically diversity and dominance, by individual species at different scales. A study of historical sightings of grizzly bears in the North Cascades ecosystem, in northern Washington, indicated selection of intermediate levels of diversity, or vegetation interspersion, in land-cover types (Agee et al. 1989). Black bears in Arkansas used low vegetation diversity less than expected and high diversity more than expected (Clark et al. 1993). Neither of these studies investigated multiple scales. Related to the selection of homogeneous vegetation types, Mace and Waller (1997) illustrated that selection of vegetation types by grizzly bears varied between scales ranging from 0.15 m² to 5 km². These studies indirectly support our findings.

Also related to vegetation pattern, close proximity to edge was frequently selected. Proximity to edge was strongly selected even after vegetation diversity had been accounted for in the models, indicating that bears might prefer environments with high variability of vegetation types within which individuals select to be closer or farther away from an edge.

There are many reasons why grizzly bears might select to be close to edges and diverse environments including hiding cover to escape from threats (McLellan and Shackleton 1989, Gunther 1990), temperature regulation, or increased forage productivity, increased foraging options, use of vegetation types that occur only in small patches, or avoidance of large blocks of homogeneous vegetation. Several of the major plant species consumed by grizzly bears are most productive in ecotone environments, such as buffaloberry under low canopy cover (Hamer 1996). Yellow hedysarum is dug and consumed by grizzly bears partly along forest edges (Hamer and Herrero 1983). Other research has suggested that locations adjacent to edge environments might be important for foraging (Schleyer 1983, Mattson 1997, Mace et al. 1999). In the early preberry season, bears might use environments closer to open edges where phenology is advanced, whereas in the late
preberry season bears might use environments closer to shaded edges where the phenology is slightly delayed.

**Characteristics of Terrain Pattern**

The pattern of vegetation types across a landscape can be influenced by variation in terrain, and so can plant species richness and diversity (Burnett et al. 1998). In a mountainous environment, ruggedness might also affect plant phenology, potentially attracting bears to areas with terrain and vegetation variability. Female grizzly bears frequently selected relatively rugged terrain. We speculate that these bears avoided the highest classes of ruggedness due to the presence of steep rock and ice. Wary females selected high levels of ruggedness at the broadest scale during both seasons. Contrastingly, habituated individuals selected ruggedness at the local 300-m scale (Theberge 2002). Other research in the eastern slopes (Theberge 2002) found that selection of steep slopes was particularly strong for female grizzly bears with cubs-of-the-year during the berry season. Also in the eastern slopes region, Gibeau (2000) found that highway crossings by grizzly bears were correlated with areas (which were 3.0-km diameter) containing high ruggedness. Our research indicates that use of high levels of ruggedness is more frequent than just highway crossings, at least for wary female bears.

Other research has postulated that female grizzly bears, particularly those with cubs, might use rugged areas to increase their security, such as to decrease their rate of detection by other bears that could be threatening (Pearson 1975, Stelmock 1981, Darling 1987, Donelon 2004), or humans. If this security-seeking behaviour exists in female grizzly bears, then one might expect that use of rugged terrain would be apparent at some scale. The finest scale in our analysis, 300-m diameter, might have been too coarse to identify hiding or escape terrain immediately adjacent to individuals. However, selection of rugged terrain occurred at the broadest scale, during all seasons. We hypothesize that wary bears select large areas of relatively rugged terrain to minimize the frequency of encounters with threats, such as other bears or humans, travelling in the valley bottoms. Russell et al. (1979) found that female grizzly bears used valley bottoms less than males, and suggested that males displaced females from this habitat.

**Influence of Heterogeneity-Variables on Immediate-Variables**

Clearly, from the foregoing, bears respond to the environment at different scales. Other studies have demonstrated correlation with resource features at multiple scales for other species such as northern spotted owls (Strix occidentalis caurina), panthers (Puma concolor coryi), and woodland caribou (Rangifer tarandus caribou) (respectively Meyer et al. 1998, Kerkhoff et al. 2000, Apps et al. 2001), sometimes documenting that not all species respond to the same scales (Wallace et al. 1995, Etzenhouser et al. 1998). In many studies of grizzly bear ecology, the variables used to investigate habitat use describe the immediate environment, for example within a few hundred metres of bear locations, with little discussion regarding the possibility that bears may be aware of, and potentially responding to, more distant environmental features (as suggested in Mace and Waller 1997).

Of the immediate-variables, both in this chapter and in other results presented in Theberge (2002), wary grizzlies consistently selected avalanche in the preberry season, and close proximity to edge, and graminoid meadows in both seasons. Consistently not selected or avoided were deciduous, water, ice/ snow, conifer-SW-facing, and rock/ soil. That these variables maintain significance despite a multitude of contexts suggests the general overriding importance of these variables to the ecology of grizzly bears in the eastern slopes region. Presumably, consistently selected vegetation types are important to female grizzly bears because they contain significant amounts of seasonal bear foods (Hamer and Herrero 1987b, Mace et al. 1996, Waller and Mace 1997, McLellan and Hovey 2001, Theberge 2002).

The results of our research indicate that bear presence is correlated with various heterogeneous landscape patterns. This trend has been suggested elsewhere, although not all species, even those in the same taxonomic family, respond to heterogeneous landscape patterns in the same way (McGarigal and McComb 1995, Etzenhouser et al. 1998, Manson et al. 1999, Naugle et al. 1999). In other research, landscape patterns influenced not only the spatial distribution of movement for a species (Boone and Hunter 1996), but also the distance moved (Wegner and Merriam 1990, Taylor and Merriam 1995). The identification of landscape pattern is dependent upon the scale of measurement (Turner et al. 1989). Consequently, identifying the relationship between wildlife movement and landscape pattern is contingent...
upon selecting the appropriate scale for investigation from a multitude of potentially applicable scales (Meyer et al. 1998). Most likely, grizzly bears within their home ranges respond to resource characteristics and landscape patterns at other scales beyond those investigated here.

Geographic Areas with High Probability of Female Grizzly Bear Occurrence

We identified 4 large areas that had a high probability of female grizzly bear occurrence. Each of these areas contained a substantial proportion of valley bottom. Three of the four areas were sites of major concentrated human development (Lake Louise, Banff and the Canmore/Bow corridor). The fourth area, the Red Deer River, Ya Ha Tinda area, south to and including the Burnt Timber drainage, has major extensive human use. Additional evidence regarding the attraction of the latter area for grizzly bears comes from the Province of Alberta’s grizzly bear trapping here during spring, 2004. Nine female grizzly bears, 8 of these adult, were caught here (M.L. Gibeau, Warden Service, Parks Canada, Lake Louise, Alberta).

MANAGEMENT IMPLICATIONS

Our research indicates that grizzly bears select areas that have attributes beyond the immediate vicinity of an individual bear at any one time. This observation is important to the management of grizzly bears in the eastern slopes region, because persistence of the species will depend, in part, upon effective habitat management across a large region. General caution has been expressed regarding the use of a constant measuring scale, such as the immediate scale often investigated in resource selection modeling, which might distort an understanding of grizzly bear habitat use by aggregating or dividing resource units causing a species to appear indiscriminate in its habitat use (Milne 1991). Despite such concerns and other suggestions that individual grizzly bears might perceive broad landscapes (Mace et al. 1996), few studies have investigated scale-dependent habitat selection of grizzly bears within their home ranges (of notable exception Mace and Waller 1997).

In the eastern slopes region, adult females selected secure areas equal to or greater than 9.0 km² (slightly larger than 3.0-km diameter) that contained potentially useable land with very low human use (Gibeau et al. 2001). Such selection for these security areas suggests that grizzly bears might perceive landscapes at broad scales. The presence and maintenance of “secure” habitat, defined as areas where an adult female grizzly bear is able to meet its foraging needs on a daily basis with low likelihood of disturbance by humans, has been recommended by other studies (Mattson et al. 1992, Gibeau et al. 2001). Grizzly bears that have access to secure habitat have low probabilities of becoming habituated or food-conditioned, and had significantly less mortality than non-wary female grizzlies (Mattson et al. 1992).

Comparisons between the results of our resource selection function models and the apparent selection of secure areas found by Gibeau et al. (2001) is difficult because of differences in methodology, particularly because Gibeau et al. (2001) did not consider the effects of scale or other selected habitat attributes. Nonetheless their recommended protection within 9.0 km² security areas is similar to our multi-scale resource selection results. These multi-scale results demonstrated that female grizzlies used areas of low non-motorized access density at the 1.5-km scale in combination with a set of other selected resources, not necessarily at the 3.0-km scale that Gibeau et al. (2001) described. We presume that these bears would select somewhat larger areas of land that were not disturbed by non-motorized human access if the optimum combination of variables were present. Substantiating this presumption is the trend in our analysis indicating that bears avoided areas that contained high density of motorized access at the 3.0-km scale. Consequently, we encourage the establishment of management programs that protect contiguous areas of selected resource attributes, with low levels of human use at the 1.5-km scale. Such management programs would be congruent with general ecological recommendations that connectivity, or lack of fragmentation, between habitats is important (Noss et al. 1996).

Large blocks of undisturbed land, such as security areas, may be important to grizzlies, but only if they also contain resource characteristics typically selected by the species. The results in this chapter suggest that bears used heterogeneous landscape patterns more than available within their home ranges. Management in the eastern slopes region needs to consider not only the maintenance of specific landscape attributes, such as vegetation edge or avalanche chutes, but also landscape structure, such as high levels of vegetation community diversity.
That relatively high levels of diversity and presence of edge environments were consistently important in resource selection potentially signifies 1) a general attraction to environments in which a variety of foods, at various phenological stages, are available, and/or 2) avoidance of large blocks of homogeneous vegetation. Increasing levels of homogeneity in the landscape could occur due to lack of periodic disturbance such as fire. The removal of fire, or near removal, from the eastern slopes ecosystem may have altered patterns of diversity and edge, allowing some vegetation types to succeed to more homogeneous states. Maintenance of natural fire regimes is recommended. Prescribed burns are an alternative, provided that the appropriate frequency, intensity, periodicity and seasonality are attained.

A set of resource characteristics was consistently selected by adult female grizzlies (Theberge 2002). To increase the likelihood of persistence of grizzly bears in the eastern slopes region, we recommend that management minimize human disturbance in areas that contain resource characteristics that are consistently selected by wary female bears. Specifically, management needs to focus upon areas that are within 60 metres of vegetation edges (Theberge 2002), that have high levels of diversity within 300-m and 1.5-km windows, and that consist of relatively rugged terrain within broad 3.0-km areas. Also of importance are graminoid meadows during all seasons, avalanche chutes during the spring, and riparian areas adjacent to water during summer and autumn. To respect the needs of grizzly bears, human activities in these areas should be carefully managed, particularly to ensure that areas containing these characteristics maintain low levels of human access within 1.5-km diameter windows. As well, management planning in the eastern slopes region should include the identification of security areas (Gibeau et al. 2001), within which management is aimed at minimizing human access in contiguous 1.5-km diameter areas or larger. Furthermore, habitat to connect areas with such attributes, even if of somewhat lesser attractiveness, is also essential if we are to avoid habitat loss and attendant grizzly bear population stress.

Our identification of geographic areas where there was a high probability of adult female grizzly bear occurrence can aid regional decision-making by highlighting locations where management action could make areas that are attractive to grizzly bears safer for their use. Because all of these areas are developed for intensive or extensive human use there is a relatively high mortality probability for adult female grizzly bears (Chapter 6.6, this report). Managing these landscapes for human use and providing for grizzly bear safety will challenge managers.

LITERATURE CITED


10.4 COMPARISON OF RESULTS REGARDING RESOURCE SELECTION MODELS FOR FEMALE GRIZZLY BEARS IN THE EASTERN SLOPES BASED ON COARSE-FILTER AND FINE-FILTER APPROACHES

Jeannette Theberge and Saundi Stevens

INTRODUCTION
The research conducted by Theberge (2002) and Stevens (2002) addresses 2 approaches to understanding landscape selection by bears (Table 1). This results in somewhat different management implications regarding grizzly bear habitat conservation. Highlighted in this chapter are substantial differences in our results, and their respective management implications. As in our previous sections, these results pertain to female grizzly bears that exhibited wary-type behaviours towards humans.

Table 1. Similarities and differences in modeling approaches taken by Stevens (2002) and Theberge (2002) to determine habitat selection of female grizzly bears in the eastern slopes of the Canadian Rocky Mountains.

<table>
<thead>
<tr>
<th>Management Implications</th>
<th>Stevens 2002</th>
<th>Theberge 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse approach for management to monitor broad changes to greenness across landscape</td>
<td></td>
<td>Finer (multiscale) approach for management where intervention and habitat conservation can focus on specific variables</td>
</tr>
<tr>
<td>Study Area</td>
<td>11,400 km² east of Continental Divide 5,000 km² west of Continental Divide</td>
<td>11,400 km² east of Continental Divide</td>
</tr>
<tr>
<td>Software to Delineate Home Range</td>
<td>Animal Movement extension in Arc View</td>
<td>KERNELHR</td>
</tr>
<tr>
<td>Collection of Bear Locations</td>
<td>Aerial telemetry</td>
<td>Aerial telemetry</td>
</tr>
<tr>
<td>Generation of Random Locations</td>
<td>Approximately 25,000 random locations distributed in and between home ranges</td>
<td>Approximately 40,000 random locations (3,000 per home range) distributed within home ranges</td>
</tr>
<tr>
<td>Order of Resource Selection (Johnson 1980)</td>
<td>2nd order - description of selected resources in study area where bears are known to occur and where they do not occur</td>
<td>3rd order - description of selected resources within the known home ranges of bears</td>
</tr>
<tr>
<td>Seasons Investigated</td>
<td>Berry Season (July 15 - October 31)</td>
<td>Preberry Season (May 1 - July 15) Berry Season (July 16 - October 31)</td>
</tr>
<tr>
<td>Approach to Research Question</td>
<td>Correlation of female bear presence with attributes and greenness parameters, largely based on Landsat reflectance</td>
<td>Correlation of female bears with attributes and landscape pattern at multiple scales, based largely on vegetation classification</td>
</tr>
<tr>
<td>Human access</td>
<td>Measured density of all human access in 1.5-km radius (equivalent to 3.0-km diameter) moving window</td>
<td>Measured both non-motorized and motorized access density in 1.5-km and 3.0-km diameter moving windows</td>
</tr>
</tbody>
</table>

Stevens (2002) adopted a coarse filter approach by investigating the correlation of the presence of bears with the variables related to greenness, a surrogate of grizzly bear habitat quality. This study area encompassed lands within and between known bear home ranges. The approach taken by Theberge (2002) permits finer scale management planning because it addresses the correlation of the presence of bears with a suite of variables related to vegetation types and landscape patterns at multiple scales. Theberge’s study area included only lands within bear home ranges.
COARSE SCALE MANAGEMENT APPROACH

Stevens (2002) concluded that density of high greenness and distance to high greenness were the most important predictors of female grizzly bear occurrence, of variables investigated. Greenness has been found to correlate strongly with grizzly bear presence (Mace et al. 1999, Gibeau 2000), and has been used to identify grizzly bear habitat across large areas (Nielsen et al. 2002). High levels of greenness represent abundance and vigour of living vegetation, particularly herbaceous and deciduous. In the Central Rockies Ecosystem, high levels of greenness are correlated with avalanche paths and areas of herbaceous vegetation types (Wierzchowski 2000). Low levels of greenness are found where phytomass is low (i.e. rock and ice). This is a relative index. In other environments, high levels of greenness have been correlated with mature agricultural crops.

The links between greenness and habitat selection of grizzly bears are not completely understood. Consequently, it may be difficult to manage specifically to create increases or decreases of greenness habitat. For example, the resulting levels of greenness after ecological manipulations, such as forest harvest or prescribed fire of varying intensity and severity, may not be predictable due to variability in successional pathways. Nonetheless, greenness may be a useful tool in monitoring broad ecological changes across jurisdictions over time, thereby indicating potential changes in the presence of female grizzly bears.

FINE SCALE MANAGEMENT APPROACH

Theberge (2002) concluded that locations of female grizzly bears were correlated with environmental conditions and heterogeneous landscape patterns at different scales. The results provide some basis for management action or habitat enhancement, particularly related to areas with the following characteristics: within 60 metres of vegetation edges, high levels of vegetation diversity within 300-m and 1.5-km windows, rugged terrain within broad 3.0-km areas, graminoid meadows, avalanche paths, or riparian areas. To maintain grizzly bear habitat, some of these characteristics can be maintained, or human activities can be strategically directed away from them.

HUMAN-USE VARIABLES

Although Stevens found in some models that female bears were selecting higher levels of human access density at the 1.5-km radius scale (equivalent to Theberge’s 3.0-km diameter scale), she also found that the confidence limits on this parameter estimate were broad, indicating large variance. Consequently, Stevens determined that the model with the best explanation of variance was a model that excluded human access density.

In contrast, Theberge concluded that access density was a significant factor influencing presence of female grizzly bears. During both seasons, female bears selected pockets of low non-motorized human access density (1.5-km scale) within larger areas (3.0-km scale) of higher levels of non-motorized human access density. Areas of high levels of motorized access density were never selected by wary female grizzly bears. Differences in the results between Theberge and Stevens are likely attributable to the different scales and variables used for modeling, the different approaches of 2nd and 3rd order selection analysis, and the lumping or splitting of categories of human access types.

Other research has suggested that the will of individual bears to access high quality habitat will prevail over their wariness towards humans (McLellan and Shackleton 1988, Mace et al. 1996, Gibeau 2000). In the eastern slopes, human presence is widespread throughout the region but concentrated in valley bottoms and side slopes. It is likely that bears are often relatively close to human-created features by default. They may be avoiding human contact through selecting pockets of low access density, hiding in vegetative cover, or being less active during times of peak human use. However, there are substantial costs for bears near human features, particularly related to the truncated longevity of individual bears (Mattson et al. 1996, McLellan et al. 1999, Benn and Herrero 2002), potentially impacting the persistence of the population.
MANAGEMENT IMPLICATIONS

Each study has different management applications. Models related to greenness (Stevens 2002), are useful as a coarse management tool. Land managers can monitor broad changes in greenness, and human activities in grizzly bear security areas that have high greenness values, across decades. This can be used as an early-warning signal to precipitate management action or habitat enhancement. Models based on vegetation pattern (Theberge 2002) provide ecological correlates with bear presence, thereby allowing land managers to actively manage specific ecological attributes, manage levels of human use in areas with concentrations of important attributes, or take other management actions. We feel that in the eastern slopes of the Central Rockies Ecosystem, it may be most appropriate to use both these coarse and fine approaches to ensure that habitat used by female grizzly bears is conserved.

LITERATURE CITED
CHAPTER 11

GRIZZLY BEAR RESPONSE TO HUMAN USE
11. GRIZZLY BEAR RESPONSE TO HUMAN USE

Michael Gibeau and Saundi Stevens

MOVEMENT AND ACTIVITY PATTERNS

Daily activity patterns of grizzly bears have been found to vary widely. Some studies have found grizzly bears to be diurnal (Stemlock and Dean 1983, Wenum 1998, MacHutchon et al. 1998). Others have found grizzly bears to be more crepuscular (Harting 1985, Gunther 1990, McCann 1991). Several authors have suggested this variability is due to grizzly bear's ability to alter their temporal and spatial activity patterns in response to human activity. One study (MacHutchon et al. 1998) found variation with age and sex classes as well as level of human activity. Mattson (1990) believed that grizzly bears response to human activity is a function of several factors including the nature and extent of historical interactions with humans, availability of human foods, demographics and size of the population, and distribution of habitats. One aspect of bears’ response to human activity ranges along a continuum from extreme wariness to habituated behavior.

In this study, Gibeau (2000) found no difference in bear movement rate for adult females between the conventional division of day versus night. However, he detected substantial difference when dividing the data by when humans were active or not active. This is consistent with the findings of Olson et al. (1997) that some differences in use patterns are attributable to human activity. Another apparent influence was observed in our intensive movement data which showed that habituated adult female bears did not take advantage of higher quality habitats (Fig. 1) in the same manner that wary bears did. While not statistically significant in this study, some differences in movement rates between wary and habituated adult females when humans were active (Fig. 2) also lend further evidence suggesting the influence of humans. The combination of habituated bears using lower quality habitats and displaying somewhat higher movement rates has obvious implications for the net energy available for growth and reproduction.

While these implications on fitness and reproduction are most acute for habituated bears they are not limited to this subset of the population. Although the sample is small, Gibeau (2000) found movement patterns of the 2 adult females within the control area also demonstrated a response to human activity. Bears within the area of restricted human access used higher quality habitat and traveled less than bears in unregulated areas despite there being less high quality habitat in the restricted area.

Overall, both wary and habituated adult female grizzly bears were affected by human presence. In the relative absence of humans, wary bears were characterized by more efficient use of higher quality habitats with less movement. Increased human presence eroded this habitat optimization to a point where habituated bears traveled further in sub-optimal habitats. Females that have access to predictable and high value foods such as meat and berries attain greater adult size, mature earlier, and have larger litters than those with access only to foods with low nutritional value such as roots (Rogers 1977, Nagy and Haroldson 1990, Hilderbrand et al. 1999, Mattson et al. 1999). Adult females are the reproductive engine of grizzly bear populations, and their success is the key to long term population persistence. Providing adult female grizzly bears with the highest level of protection possible should be a management priority. Managing human impacts on individual grizzly bears and the population is key to this provision.

Mueller (2001, Mueller et al. 2004) found that subadult and adult bears differed significantly in their spatial distribution on the landscape. These differences in spatial distribution may be a result of intraspecific avoidance. Studies suggest that a consequence of intraspecific avoidance is differential distribution of bears by age and sex class (Hornocker 1962, Egbert and Stokes 1976, Tate and Pelton 1983, Mattson 1990). Hornocker (1962) Egbert (1978) and Wielgus (1993) suggested that adult males were dominant, followed by females with young, single adult females, and subadults. Subadult females were the least dominant of all. According to this hypothesis, subdominant animals should avoid dominant animals (i.e. adult males and male-occupied habitats) according to their size and vulnerability to injury or predation, or dominance and aggressiveness (Hornocker 1962, McCullough 1981, Stringham 1983, Wielgus 1993). In areas where humans and grizzly bears coexist, such as the Bow River Watershed, adult grizzly bears avoid areas close to people, probably because such avoidance gives greater security (Gibeau 2000). Subadult bears may use habitat with less security (closer to humans) to avoid adult bears. The closeness of humans may provide refuge and an opportunity for subadult bears to use higher quality foods otherwise pre-empted by dominant adults (Mattson et al. 1987, McLellan and Shackleton 1988, Gibeau 2000). During the pre-berry season,
subadult bears, particularly subadult female bears, in the Bow River Watershed, were found significantly closer to high-use roads and high quality habitat than were adult bears.

![Box and whisker plot](image)

Figure 1. Box and whisker plot of the range of use of high quality habitat for wary and habituated adult female grizzly bear in the Bow River Watershed, Alberta, 1994-1998. The box indicates the median, 25% and 75% quartiles and whiskers are the largest values that are not outliers.

![Box and whisker plots](image)

Figure 2. Box and whisker plots of distance traveled by time period for wary and habituated adult female grizzly bear in the Bow River Watershed, Alberta, 1994-1998. The box indicates the median, 25% and 75% quartiles and whiskers are the largest values that are not outliers.

Similar relationships have been found in Yellowstone National Park where adult male grizzlies were less likely to be nearby humans and more likely to use backcountry areas while subadults were more likely to use areas nearest to humans (Mattson et al. 1987, Mattson et al. 1992). Adult females and subadults also tended to occupy areas near humans more than adult males along spawning streams on Admiralty Island (Warner 1987), along roads in the Flathead Valley of British Columbia (McLellan and Shackleton 1988) and along roads in Denali National Park, Alaska (Tracy 1977).

Although spending time near humans in the Bow River Watershed may give subadult bears access to better habitats, it also puts them at significantly greater risk of mortality, both from management removals due to habitation problems and mortality on major transportation corridors such as highways and railroads. Benn and Herrero (2000) reported that 100% of 95 human-caused mortalities in Banff and Yoho National
Parks between 1971-98 occurred within 500 meters of a road or 200 meters of a trail. McLellan et al. (1999) reported that annual survival rates of subadult male grizzly bears in the Rocky Mountains between 1975 and 1997 were less than other age-sex classes, and that subadult male mortality rates due to management and citizen control killing were higher than other age-sex classes. Garshelis et al. (2005) found that for grizzly bears studied as part of the ESGBP subadult female survival was 91-92% and this was not significantly different from adult female survival, 95-96%. Subadult male survival was 69-74% and was significantly lower than adult male survival, 86-89%. Subadult males were 3X more likely to die than adult males. Subadult males tend to disperse to areas outside their natal ranges (LeFranc et al. 1987, Blanchard and Knight 1991, Schwartz and Franzmann 1992, McLellan and Hovey 2001b). Young males may therefore be predisposed to conflict with humans because they are more mobile, tend to use unfamiliar areas, and are often found close to humans (Clevenger and Pelton 1990, Swenson et al. 1998, Pease and Mattson 1999). As a consequence, mortality rates of subadult male bears tend to be higher than for subadult female bears (McLellan et al. 1999).

Their association with human activity also makes subdominant bears significantly more vulnerable to habituation to people than other bears (Gunther 1990). Habituation has major implications to bear populations confronted by even moderate densities of humans (Mattson 1990). Although habituation may increase the efficiency of bear habitat use in some instances by reducing displacement and minimising the frequency of energy-demanding responses, habituated grizzly bears are subject to higher mortality rates in all future years (Meagher and Fowler 1989, Mattson et al. 1992, Pease and Mattson 1999). Studies in Yellowstone National Park have shown that bears habituated to human activity but still eating natural foods were killed 3 times as often by humans as bears that were not habituated (Mattson et al. 1992). In some cases, habituation leads to greater risk of injury to humans (Herrero 1985, 1989). Herrero (1989) found that for all 12 grizzly bear-inflicted deaths that occurred in Glacier National Park, Montana, Yellowstone National Park, and Banff National Park between 1967 and 1986, the bear involved was either food-conditioned and/or habituated. Results from Mueller (2001) indicate that in the Bow River Watershed subadult male and female grizzly bears are prone to interaction with humans. This translates directly to increased risk of human-caused mortality.

Jalkotzy et al. (1999) analyzed habitat use by grizzly bears in the Lake Louise area. Intensive monitoring of the movements of adult females over 24 hour periods in the immediate vicinity of the Skiing Louise lease provided insights into how grizzly bears make use of a human-dominated landscape. They found that female bears did not use ecosites within the Baker and Skoki BMU’s between 1994-98 in a random manner. Use of ecosites and consolidated cover types varied seasonally. Cleared ski runs on the Skiing Louise lease were strongly selected for in spring. Wet seeps on and in the vicinity of ski runs with their communities of common horsetail, and various nutritious grasses and sedges, were attractive to bears. Although selection for the type weakened in the summer, attraction to these artificial openings in the summer continued as green-up progressed up the slope. Ski runs were avoided in the fall probably because better food sources were available elsewhere. In spring and summer, adult female bears #30 and #46 tended to be closer to ski runs and the base lodge at night than during the day (Fig. 3).

In addition, both bears tended to be closer to the ski runs than to the base lodge in spring and summer. Use of the Skiing Louise lease in fall was limited to the Temple/Ptarmigan area where bears frequently fed on crowberry.
RESPONSE TO DEVELOPMENTS

Gibeau et al. (2002) found of the four types of human developments investigated, the Trans Canada Highway (TCH) was avoided most by grizzly bears. Female bears avoided the busy freeway regardless of the habitat quality or time of day. Males, and especially subadult males, were found closer to the TCH when within or adjacent to high quality habitat and during the human inactive period. These observed responses may not be solely due to the TCH, but to the higher overall density of humans associated with the valley that includes the TCH. Several authors believe that grizzly bears become accustomed to predictable occurrences (Herrero 1985, Jope 1985), including traffic (McLellan and Shackleton 1989b) although our results have suggested otherwise for high-speed, high-volume highways. There is a point when the combination of traffic volume and highway configuration overrides a bear’s attraction to high quality habitats (Fig. 4a).
Figure 4. Profile plots of the interaction between high quality habitat and time period for (A) TCH, (B) high use paved roads, (C) high use trails, and (D) high use features, for grizzly bears in the Bow River Watershed, Alberta, 1994-1998.
Avoidance of roads by grizzly bears has been documented by Tracey (1977), Harding and Nagy (1980), Archibald et al. (1987), Mattson et al. (1987), McLellan and Shackleton (1988), Kasworm and Manley (1990), and Mace et al. (1996). We too documented bears further from roads when distant from high quality habitat which we interpret as avoidance behavior. In this environment, however, bears were found closer to paved roads than would be predicted, presumably to acquire high quality food resources. High quality habitat is a strong attractant. Mace et al. (1996) demonstrated that avoidance of roadside buffers by grizzly bears generally increased with traffic levels and road densities, but bears did use important habitats adjacent to roads with low to moderate traffic levels. This neutral use or positive selection toward habitats near roads implied that important habitat resources possibly occurred near roads in their study area also.

Unlike paved roads that were located in valley bottoms and good quality habitats, high use trails were widely distributed throughout all types of habitats within the study area. Gibeau et al. (2002) found bears were closer to trails during the human inactive period when within high quality habitat and further from trails when distant from high quality habitat (Fig 4c). In the Swan Mountains Montana, Mace and Waller (1996) concluded that grizzly bears using hiking trails have become negatively conditioned to human activity and that they minimized their interaction with recreationalists by spatially and temporally avoiding high use areas. Our data suggest the same pattern in the absence of high quality habitat.

Kasworm and Manley (1990) reported that, overall, grizzlies were displaced less by trails than by roads. Our results suggest otherwise for this study area. Gibeau et al. (2002) observed avoidance of high use trails when distant from high quality habitat. This may be a reflection of a greater opportunity for bears to select high quality habitat in the relative absence of humans. In this study area, grizzly bears may not have the opportunity to truly “avoid” paved roads without forfeiting access to much of the high quality habitats.

Gibeau et al. (2002) also found bears took advantage of high quality habitat near development while humans were inactive. While this trend was evident for all types of human developments, it was most pronounced in association with features (Fig 4d). Mattson et al. (1987) and Reinhart and Mattson (1990) found that habitats were substantially under used especially during the day near town-sites and recreational developments. Our results show that grizzly bears were more likely to use roads, trails and human facilities at night or when unoccupied. This is consistent with other studies (Harting 1985, Nadeau 1987, McLellan and Shackleton 1988, Gunther 1990).

Gibeau et al. (2002) concluded from their observations and the literature, that there were significant differences in grizzly bear response to roads, trails and major development features categorized by sex, age class, proximity of high quality habitat and time of day. High human presence is likely to be the reason most grizzly bears are unwilling to use habitats near busy transportation corridors. This avoidance behavior was strongest in the adult segment of the population where we believe males selected for high quality habitats and an absence of humans. Those males that were willing to exploit high quality habitat near roads, did so at night and where hiding cover was present. Adult females were the most risk adverse cohort, choosing to avoid humans instead of seeking out the highest quality habitats. Adult females selected areas with a high degree of security for raising cubs (Gibeau et al. 2001), which in some cases also meant avoiding adult males. With the safest and highest quality habitats taken up by adult males and resident females, subordinate bears including some adult females, were forced to use sub-optimal habitats including those with high human presence. Our data demonstrated that subadults were almost always closer to humans than adults were. Unable to successfully compete elsewhere, these bears were relegated to using habitats close to people and developments. Bears in close proximity to humans are more apt to become habituated to people. While habituated bears appear to successfully use habitats near humans, they also are most likely to die at the hands of humans (Mattson et al. 1992, McLellan et al. 1999).

More detailed analysis of the effects of highways on grizzly bears by Chruszcz et al. (2003) found grizzly bears tended to be closer to roads with low traffic volume than high traffic volume, and that habituated grizzly bears were closer to roads than wary grizzly bears. These results lead them to believe that bears use high quality habitat near roads as they become habituated to highway traffic. On low-volume roads, where vehicle disturbance is less severe, bears adapt to the use of roadside habitat more readily resulting in different patterns of distribution around the two road types. Given the high traffic volumes in our study area, traffic noise is relatively constant, predictable and has no negative stimulus associated with it. Therefore, it is likely bears learn to use habitat adjacent to roads.
The association or indifference of BNP grizzly bears to roads does not suggest that roads do not affect their movements. There is ample evidence that highways can limit bear movements in the Bow Valley and adjacent lands (Serruoya 1999, Gibeau 2000). Although grizzly bears were found closer than expected to low-volume roads, they will not necessarily readily cross all road types or survive crossings. Our results indicate that grizzly bears were reluctant to cross high-volume roads like the TCH and crossings were generally associated with movements into better habitat (Chruszcz et al 2003). Low-volume roads were more permeable to grizzly bears than the TCH.

For both road types in our study area grizzly bears crossed roads in areas where habitat quality was high. However, when grizzly bears crossed high-volume roads they moved into areas of higher quality habitat. This pattern did not occur on low-volume roads, suggesting that there is a trade off between the risks of crossing roads and benefits in terms of access to higher quality habitat. Furthermore, road crossings were more likely to occur in areas where dense vegetation was adjacent to roads (Chruszcz et al 2003). Bear preference for cover when moving near or crossing roads has been observed elsewhere (McLellan and Shackleton 1989; Brandenburg 1996). Cover may be an important requirement for successfully crossing roads and provide security from road-related disturbance.

Two patterns emerged from the Chruszcz et al. (2003) study: the avoidance of high-volume roads in a major transportation corridor, and the importance of high quality habitat in determining grizzly bear movement decisions relative to roads. They found a clear dichotomy in the behaviour of bears relative to high and low-volume roads. The reduced cross-valley permeability caused by the presence of the TCH may result in harmful population effects in view of the great mobility and extensive spatial requirements of grizzly bears (Forman et al. 2002). Because the TCH only acts as a partial barrier (or filter) it is unlikely that isolation effects will occur in this population. However, the cumulative effects of human use and development, railways and highways within the Bow Valley can limit access to important habitats, thereby negatively impacting grizzly bears in the BNP ecosystem (Gibeau et al. 2002).

**INDIVIDUALITY AND HABITUATION**

Wildlife response to humans and our activities occur in different circumstances and in differing magnitudes (Whittaker and Knight 1998). Wildlife also behave differently in different locations and during different activities, and the learned outcomes of all these interactions affect subsequent interactions (Gilbert 1989). One important yet confounding variable, both in the literature and within our data, was the level of habituation (Whittaker and Knight 1998) of some individuals. Habituation (Herrero 1985) may permit some bears to exploit habitats near roads, trails and developments, especially if human use is spatially and temporally predictable (Tracey 1977, Jope 1985, McLellan and Shackleton 1989a, Olson et al. 1990). Several studies have suggested there are differences among sex, age and reproductive classes in the likelihood and level of habituation to humans (Olson et al. 1990, Mattson 1990). Our observations on responses of grizzly bears to various human developments reflect some of these differences, even though the majority of study bears were not considered habituated.

Social structure may also have a bearing on spatial distribution of a bear population. In Yellowstone National Park, Mattson et al. (1987) demonstrated that cohorts of subordinate bears were found in poorer-quality habitats near developments, probably displaced from better habitat by more dominant classes, particularly adult males. McLellan and Shackleton (1988) also determined that adult males used remote areas whereas adult females and some subadults used areas closer to roads. In Banff National Park, 1985-1998, the female portion of human-caused grizzly bear mortalities was 80% and most occurred near roads (Benn and Herrero 2002). While our results pointed to differential use by sex and age, we were unable to determine whether this distribution is a natural phenomenon or the result of competition for space with humans.

Mueller (2001) found the five subadult bears in the Lake Louise area of Banff National Park showed significant variability in their behaviour patterns around human activity and human development during the study period (Fig. 5). Habituated subadults were more likely to die than were wary individuals.
Differences in individual behaviour play prominent roles in population dynamics (Armitage 1986, Lomnicki 1988). Individual differences may be expressed in social behaviour, recruitment and dispersal (Armitage 1986). Social hierarchies create a major force for dispersal (Christian 1970, McLellan 1990). Population density is also a large component of dispersal. When densities are very low, a higher proportion of subordinate individuals can find suitable areas in the preferred habitat, the number of dispersing animals is reduced, and the survival of subordinate animals is greatly increased (Christian 1970). When densities are high, subdominant, predominantly subadult bears, are forced to disperse from their birthplace and find space in suitable habitat unoccupied by more dominant members of the same species (van Horne 1983). Dispersing subadults may be forced into competition with members of other species or humans as they move into new habitats (Christian 1970). In the Bow River Watershed this may be the case for subadult grizzly bears in general (Mueller 2001, Mueller et al. 2004), but comparisons of individual bears suggest that this may be more likely the case for specific subadult bears.

Genetics and experience both affect the expression of individuality (Fagen and Fagen 1994, Alcock 1989). Stirling and Derocher (1990) suggested that through learning, some bears may develop individual differences in food preferences, or how they respond to disturbances. Lomnicki (1988) argued for the adaptive significance of individual variation within populations. By producing young of varied phenotypes, a female increases the probability that over the long term some of her descendants will survive in varied and unpredictable social and ecological environments (Wallace 1982, Armitage 1986). Results from Mueller’s (2001) comparison of individual subadult bears in the Lake Louise area suggest that variability may play a large role in their survival and success in such a developed landscape.
LITERATURE CITED


FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005


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FINALE REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005
CHAPTER 12
HABITAT EFFECTIVENESS AND SECURITY AREA ANALYSES
12. HABITAT EFFECTIVENESS AND SECURITY AREA ANALYSIS

Michael Gibeau

As demands on the land increase, cumulative effects result from individually minor yet collectively significant uses occurring over space and time. Cumulative effects analysis (CEA) assesses the effects on a system of spatial and temporal perturbations resulting from human activities (Beanlands et al. 1986). CEA explicitly deals with effects, and most importantly, whether those effects exceed or fall short of thresholds compatible with population goals of a given species or guild of species. Hence, CEA and its subsequent models, are tools to perform proactive conservation (Weaver et al. 1987) of threatened or sensitive species and landscapes.

Initial analysis of habitat effectiveness, done in the early 1990’s, played a key role in underscoring the effects of development in the mountain National Parks (Gibeau 1998). For many this evaluation was the first realization that much of the mountain national parks are not inherently prime, undisturbed grizzly bear habitat. Better habitat lies to both the east and west in human-dominated multiple-use lands. The disturbance component of the model suggests the ability of the landscape to support bears has been significantly reduced by widespread human presence. The results predicted widespread habitat alienation in areas previously considered core refugia for grizzly bears in the Canadian Rocky Mountains (Figure 1).

Figure 1. Habitat Effectiveness Map for bear management units in Banff, Yoho and Kootenay National Parks.
This finding questioned the long-term ability of the landscape to support a viable population. Traditional types and levels of human activities are widely accepted within national parks and had not been viewed as detrimental to grizzly bears until this point.

In a more detailed analysis of habitat effectiveness in the Lake Louise area, Jalkotzy et al. (1999) found large continuous pieces of potential grizzly bear habitat were associated with major valley bottoms, in particular the Bow River, the Pipestone River, Baker Creek, and the upper Red Deer River. Grizzly bear habitat at higher elevations tends to have a patchy distribution relative to the valley bottoms. Temporal variation in potential habitat quality for grizzly bears results from the changing availability and importance of plant foods and other food sources throughout the year. The food habitats component of the habitat effectiveness model rated habitat polygons for grizzly bears on a monthly basis to take into account this variation. As a result, the relative quality and quantity of habitats rated as good or very good for grizzly bears in the potential habitat model changed with the seasons. While the validity of expert determined habitat suitability models, a key component of habitat effectiveness modeling, has been questioned (Nielsen 2003), the fundamental point that human landscape use extensively compromises grizzly bear habitat use, remains.

With updated human use maps, Jalkotzy et al. (1999) produced realized habitat maps for each BMU in May, August, and October. Their maps predicted the extent to which the amount and distribution of grizzly bear habitats in all BMU’s were altered by human disturbance. First, the extent of grizzly bear habitat within the BMU was reduced. There are fewer places for bears to forage. Second, the sizes of the remaining patches of good and very good grizzly bear habitat were reduced. There are fewer places where grizzly bears can remain within the BMU without being disturbed by humans. Finally, linkages of good and very good habitat between larger pockets of undisturbed lands were reduced in size and number. Overall their analysis demonstrated further fragmentation of a naturally-fragmented landscape makes it more difficult for grizzly bears to move throughout the BMU’s without contacting humans.

**SECURITY AREA ANALYSIS**

In the past, habitat effectiveness modeling was the primary tool used to measure the impact of human activities on bears (USDA Forest Service 1990, Gibeau 1998). The model fell short, however, in estimating the human encounter rate and mortality risk that is equally important as foraging opportunities for population persistence. Security area analysis provides managers with a measure of the human encounter rate for adult female grizzly bears at a much more refined scale than the habitat effectiveness model. Security areas help reduce the number of habituated bears, bears killed out of self-defense, and bears killed or removed by management agencies because of unacceptable behavior (Mattson 1993).

Gibeau et al. (2001) defined security areas and land not secure due to rock and ice, human use or size for each jurisdiction in the Central Canadian Rocky Mountains (CRE) by comparing a map of the available landscape with a minimum daily area requirement of 9.0 km² based on an adult female's daily foraging radius. The percent of productive land base where adult female grizzly bears have a low probability of encounters with people (secure) depends on the amount of productive land available to a bear and the extent of human influence. Alberta’s Kananaskis Country (52% secure habitat) and Alberta provincial lands (63%) did not meet the current target level of 68% considered to be adequate security set by the USDA Forest Service (1995) in the Northern Continental Divide grizzly bear ecosystem in northwest Montana. Only the combined National Parks (68%) and British Columbia provincial lands (68%) met the USDA’s target level. Results suggest that some of the best chances for grizzly bear persistence come from outside National Parks (McLellan et al. 1999), and hence a cooperative and coordinated management approach is critical.

Analysis of security areas over time for Banff National Park and Kananaskis Country clearly demonstrated the decreasing size over time of relatively undisturbed habitat units (Figure 2). This habitat fragmentation has occurred throughout Banff National Park and Kananaskis Country, but is dramatic in the Bow River Valley. The decreasing size of security areas was paralleled by a significant decrease in total amount of security area available throughout Banff National Park and Kananaskis Country.
Figure 2. Analysis of grizzly bear security areas for Banff National Park and Kananaskis Country for past (1950s), present (1999), and future (2020s).

Gibeau et al. (2001) results also characterized habitat security at the level of an adult female grizzly bears’ home range. For 28 adult female bears throughout the region, an average of 69% of the home range was secure. Female bears within Banff National Park, however, averaged only 60% security within their home ranges.

A more recent analysis by Stevens (2002) reran the secure area model incorporating the most recent spatial data on human use. Those results found a decrease in percent of available land base that was secure habitat across all jurisdictions. British Columbia provincial lands continue to have the largest percentage of secure habitat (50%), followed by Alberta provincial lands and National Parks with 43% secure habitat in both, and Kananaskis Country with 36%. The results suggest that either human activity and development has increased in the CRE since 1998, when Gibeau et al. (2001) developed their human use models, or the original map did not capture all the human activities. Most likely there was both an increase in development and more accurate mapping of human activities. Currently, no jurisdictions in the CRE meet the USDA Forest Service target level of 68% secure habitat (IGBC 1998).
Stevens (2002) also included habitat quality in the recent evaluation of grizzly bear security (Figure 3). Results show a small proportion of each jurisdiction encompasses secure high quality habitat. British Columbia provincial lands have the largest percentage (13%) of their available land base in secure high quality habitat. Ironically, in National Parks where it is assumed that productive core refugia for grizzly bears exist, there is the least amount of available land base in secure high quality habitat (5%). In Banff National Park, an average of 4% of BMU’s are secure high quality habitat, followed by 6% in Yoho, 7% in Kananaskis Country and 12% in Kootenay National Park. It is important to identify these areas of high quality secure habitat so that managers can work to prevent further loss of habitat from the accelerating pressures of human use and ensure they remain accessible to grizzly bears over the long term.

![Secure Area map combined with habitat quality delineating secure high, moderate and low quality habitats in the Central Rockies Ecosystem. (credit: S. Stevens)](image)

Security at the level of an adult female grizzly bears’ home range revealed that for 30 female grizzly bears in the East Slopes, an average of 39% of the home range was secure, with only 7% secure high habitat quality (Table 1). For 10 adult female grizzly bears in the West Slopes, an average of 62% of the home range was secure and 22% secure high quality habitat. Secure high quality habitat for the East Slopes bears ranged between 0 and 34% of the home range (Table 1). Secure high quality habitat for the West slopes bears...
ranged between 7 and 47% of the home range (Table 1). This reduction in secure area may be attributed again to the increase of human use documented, or better mapping of human use. The results raise the question whether this level of security is sufficient for a long term viable grizzly bear population and if interventions are necessary to increase the amount of secure high quality habitat. This is particularly important since the Bow River Watershed grizzly bear population’s slight, positive growth rate, was possible because of 95-96% survival from year to year by adult females (Garshelis et al. 2005).

Table 1. Percent of the available land base that is secure high, moderate and low habitat quality for female grizzly bears in the East and West Slopes study areas. (credit: S. Stevens)

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LITERATURE CITED
CHAPTER 13

IMPLICATIONS OF HISTORICAL, CURRENT, AND LIKELY FUTURE TRAJECTORIES OF HUMAN LAND USES AND POPULATION GROWTH TO GRIZZLY BEARS IN THE ALBERTA PORTION OF THE CRE
13. IMPLICATIONS OF HISTORICAL, CURRENT, AND LIKELY FUTURE TRAJECTORIES OF HUMAN LANDUSES AND POPULATION GROWTH TO GRIZZLY BEARS IN THE ALBERTA PORTION OF THE CRE

Brad Stelfox, Stephen Herrero, and Delinda Ryerson

ABSTRACT
A progression of landuses developed and deployed during the 20th century in Alberta were responsible for significant economic growth and human population expansion, but also lead to the loss of grizzly bear habitat throughout much of the province. The dominant “bear-incompatible” landuses accounting for landscape conversion have included cropland agriculture, livestock grazing, and urban, suburban, and acreage expansions. Other landuses, most notably forestry, hydrocarbon industry, and the recreational sector, have left their anthropogenic footprint extensively across historic and current grizzly habitat, but their influences on grizzly bears are expressed more in terms of increased bear mortality than in lost habitat. Collectively, these landuses require an impressive network of linear features (major roads, minor roads, hiking/biking trails, transmission lines, seismic, pipelines, etc.), now in excess of 1 million km in Alberta, which in turn have created an access infrastructure that permits Albertans to travel extensively throughout the boreal and foothill forest communities of Alberta. Against this historic back-drop, the Central Rockies Ecosystem represents important remaining but threatened habitat for Alberta’s grizzly bears.

The loss of actual grizzly bear habitat area in recent decades is relatively small and mostly confined to the periphery of current habitat distribution. These incremental losses generally express themselves as livestock range improvement projects, acreage complexes, front-country accommodations, and a host of small, yet numerous features of the energy sector. More insidious, from a grizzly bear mortality probability perspective, is the rapidly increasing presence and activity of humans along and proximal to the existing and expanding transportation networks in remaining grizzly bear habitat. Increasing visitation rates by humans for recreational (hunting, camping, hiking, biking, trail riding, off-roading) and non-recreational (personal and commercial driving) purposes have lead to an increase in the number of bear-human encounters, and the frequency by which these encounters result in the intentional or unintentional death of bears.

The issue of bear/human encounters in the Central Rockies Ecosystem will intensify given the certain expansion of mountain and foothill commuting towns such as Canmore and Bragg Creek and the mobility and increase of a Calgary population approaching 1 million. Whereas Calgary has grown by an average annual rate of 4% in area and 2.5% in population during the past several decades, the growth of some of its satellite communities and acreage complexes has been even higher. If these growth rates persist in the coming decades, the City of Calgary will contain ~1.5 million people by 2030 and the Central East Slope commuting towns will be home to greater than 100,000 foothill and mountain residents. As this young, prosperous human population satisfies its increasing appetite for front-country and back-country recreational pursuits, the attendant bear mortality may overwhelm the conservative reproductive rates exhibited by grizzly bear females in this region. The current 3.1 million visitors (resulting in 7.7 million visitor days March 2004–March 2005) traveling through the entrance of Banff National Park is likely to grow to 10 million annual visitors by 2030, and this growth is likely to be accompanied by increased levels of both front-country and back-country recreational activities. While much of the current pressure of human residential expansion occurs along and proximal to the Bow River Corridor, it is likely that acreage complexes and commuting towns will expand in a southern direction along the eastern front ranges of the Rockies, as traditional cattle grazing operations are lost to poor economic performance and subdivision opportunities. Unless managed effectively, the combined mortality rate caused by intentional (legal hunting, poaching, self-defense) and unintentional (vehicular mortality, bear destroyed because of adverse interactions with humans) events threatens the future of grizzly bears.

As the area, length and intensity of linear features in Alberta continues to grow, it is becoming increasingly clear that access management has been neglected across large tracts of remaining grizzly bear habitat. The
current situation, with few exceptions, where all Albertans can travel any way, for any reason, at any time, across an expanding network of roads, trails, seismic lines, pipelines, and transmission lines, is untenable to the longterm maintenance of a healthy regional grizzly bear population. Creating awareness by Albertans of the need to maintain adequate amounts of relatively undisturbed habitat for sensitive species such as grizzly bears remains an enormous, but essential, challenge.

**INTRODUCTION**

The East Slopes of southwestern Alberta provide important habitat to two widely recognized and charismatic mammals. For the grizzly bear the East Slope Region represents a remnant of habitat that once spanned all the province’s biomes. Relative to the early 1800’s, when the population was many thousands, today’s grizzlies number fewer than a thousand (Kansas 2002, Stenhouse et al. 2003), and are restricted to a small portion of their original distribution.

In contrast, the trajectory of distribution and density of humans has been the mirror opposite. During the past two centuries, the human population has increased by multiple orders of magnitude, and their distribution has expanded to occupy all but the most inhospitable habitat types.

These opposite trajectories are not coincidental but historically reflect a very direct, incompatible, and unbalanced relationship between the two species. As the human population expanded across Alberta, its technological ability to convert native plant communities into a suite of landuse practices (croplands, grazing lands, towns, cities, recreational infrastructure, forestry and energy sectors, road networks) created a bow wave of conflict that reduced bear populations directly through mortality, or indirectly through loss of preferred habitat types.

Today, grizzly bears are restricted to about one-third of the province (Kansas 2002, Herrero and Higgins 2003), and to mountain and foothills habitats, much of which is designated as either federal or provincial parks. The pressure by humans and their landuses on remnant bear populations has not subsided. Most problematic to wildlife managers is the recognition that Alberta’s rapidly expanding human population looks enviable to the mountains and foothills as an idyllic environ in which to live, recreate, and conduct landuse.

Relative to other regions supporting grizzly bear populations, grizzly bears in the Alberta portion of the Central Rockies Ecosystem (CRE) (Figure 1) (Komex International 1995) live in and nearby one of the most developed and populated landscapes in North America (Gibeau 2000, Herrero et al. 2000). The human population of nearby Calgary grew by 16% between 1996 and 2000, and now exceeds 900,000 (Statistics Canada, 2001). Nearby Banff National Park receives 7.7 million visitor days per year (Personal communication Dave Dalman and Frank Grigel, Parks Canada, Banff and Calgary, respectively) and its visitorship is growing by ~2.8% annually (Banff National Park Census data). There is little grizzly bear habitat in the Alberta portion of the CRE that is secure, where a female grizzly bear can meet her daily needs without encountering people or some risk of human-caused death (Gibeau et al. 2001, Nielsen et al. 2004). Because grizzly bear in the CRE have low density, conservative reproduction, and large home ranges (et al. 2005) their human-caused mortality rate must remain low if populations are to persist (Herrero et al. 2000). Bear managers often use a target of not more than 4% human-caused mortality per year (with not greater than 30% of this mortality being females) as one that will sustain a non-declining grizzly bear population (Harris 1986). Currently, the grizzly bear population inhabiting the Bow River Watershed areas of Banff National Park and Kananaskis Country, where they are not legally hunted (except by Treaty Indians), appears to have a slight positive trajectory (Garshelis et al. 2005). However, population data indicate that if the adult female survival rate declines from 95% to 90%, this would likely lead to a population decline. A source/sink structure may exist within the broader CRE grizzly bear population with the Bow River watershed population being the source and other portions of the CRE with possible greater mortality being a sink (Stenhouse et al. 2003).

Landscape access and landuse density are primary variables that have been shown to correlate with human-caused grizzly bear mortality (McLellan 1989, USDA Forest Service 1990, Benn and Herrero 2002). Grizzly bear mortality is a function of the frequency of encounters with people and the potential lethality of these encounters (Mattson et al. 1996). Legal hunting for grizzly bear is the primary human-caused source of grizzly bear mortalities in the British Columbia portion of the CRE. In B.C., the landscape is more productive, and appears to produce enough grizzly bears that hunting is a viable management option (Peek et
al. 2003). In Alberta south of the Bow River, there is almost no grizzly bear hunting, since the bear population cannot support it (Nagy and Gunson 1990). Here human-caused mortalities and removals are associated with bears getting into trouble over human-food attractants, being shot in self-defense by ungulate hunters, being hit on highways, killing livestock, being poached, and other associations that are perceived to threaten human activities (Benn 1998, Gibeau and Herrero 1994 – 2002, Gibeau and Stevens 2003). Even in areas where grizzly bear hunting does not exist, such as the Yellowstone Ecosystem and Kananaskis Country, people with firearms, such as ungulate hunters, pose far more danger to grizzly bears than do unarmed hikers. Killing of grizzly bears in self-defense associated with ungulate hunting has become the greatest source of human-caused grizzly bear mortality in the Yellowstone Ecosystem (Kaminski, T., US Forest Service, Montana; personal communication). Road access is the primary landuse factor that increases the number of people in grizzly bear habitat.

In the CRE, grizzly bears exist in a multiple use landscape that is experiencing greater development pressure each year. Personal recreation and commercial activities such as forestry, oil and gas, residential development, and tourism and recreation continue to increase road and trail access to grizzly bear habitat. Roads not only increase mortality risk for grizzly bears, but compromise habitat use (McLellan and Shackleton 1988, USDA Forest Service 1990, Mace et al. 1996, Gibeau 2000). They also fragment habitat and populations thus further stressing population viability (Proctor 2003). Resource development is fueling rapid regional human population growth that, through positive feedback, creates more pressure for development. Maintaining grizzly bears in the Alberta portion of the CRE in this context will require landscape development and use planning and management that takes into account the needs of grizzly bears. These needs can best be respected by managing human-caused grizzly bear mortality rates at sustainable levels. To do this will require maintaining landscape conditions such as access density that are known to support low human-caused grizzly bear mortality. Grizzly bear hunting could be banned in the British Columbia portion of the CRE, as it has been in most of Alberta south of the Bow River, but this would only delay the need to manage access and industrial uses.

Figure 1. The Canadian Rockies Ecosystem (CRE). Graphic prepared by Scott Jevons.
CHANGING LAND USE AND INCREASING HUMAN POPULATIONS

As grizzly bears face an increasingly uncertain future in Alberta (Figure 2), resource managers struggle to find new ways of conveying a message to Albertans about the clear trade-offs occurring between expanding landuse practices and sustainability of regional grizzly bear populations. The data that follow are intended to help tell a compelling story about historic, current, and likely future trends in landuses in the East Slopes Grizzly Bear Study area.

Figure 2. This Darksky satellite image (1990’s) illustrates the belt of intensive landuse (shown as light emissions associated with the energy sector, transportation networks, settlements, cutblocks, and agricultural matrix) proximal to the foothill and mountain habitats of the grizzly bear in Alberta. In comparison to lands further east, the cordilleran distribution (shown in yellow) of today’s grizzlies is relatively pristine, yet the landuse footprint in the Crowsnest, Bow, and Athabasca River valleys is clearly emerging in the image above.

THE EXPANDING METROPOLIS OF CALGARY AND SURROUNDING COMMUNITIES

The city of Calgary has enjoyed remarkable population growth during the past several decades (Figure 3), much of which has been fueled by the prosperity of the province’s energy sector. As Calgary’s population has expanded, so has the footprint of this urban centre (Figure 4), consuming surrounding native grasslands and agricultural fields at a startling rate (Figure 5). The peripheral growth has occurred in all directions, but has been particularly noticeable to the south and along its western borders where the city creeps west into the foothills. If Calgary continues its growth trajectory at historic rates, it would become a metropolis of 2 million people by 2030 (Figure 3), a realization that should cause concern as to where these people will reside and enjoy their recreational activities. Human census data from Statistics Canada (2001) indicates that ~100,000 people reside in and around the communities of the East Slope between Sundre to the north and the Crowsnest Pass to the south.

Figure 5 illustrates the historic growth of the urban footprint of the greater Calgary region between 1924 and 1998 (the red dots are geographic markers along the Bow River that assist the reader with orientation). If Calgary continues to grow at the rate observed during the past several decades, the city will quadruple from its current footprint of 394 km² within 3 decades (Figure 6). If the Greater Calgary Region were to reduce its footprint growth to 3% annually (a 33% reduction in growth relative to historical rates), the footprint in 2030 would be 2.5 times as large as today (Figure 7). It is interesting that Calgary continues to grow outward (suburbia, subdivisions) at a rate higher than it is growing upward (apartments, condominiums), and hence continues to decline in human density throughout the past century (Figure 8).
Figure 3. Historical and projected (at 2, 2.5, and 3% annual growth) future population of Calgary. Historical data provided by Statistics Canada.

Figure 4. Historical and projected (at 2, 2.5, and 3% annual growth) future footprint (km²) of Calgary. Historical data based on air photo chronosequence.
Figure 5. A comparison of the urban perimeter of Calgary in 1924 (18 km², 7 mi²) and 1998 (394 km², 154 mi²), right. The white box found in the left photo is a section (1 x 1 mile; 1.6 x 1.6 km). The image on the right shows the progressive perimeter of Calgary (based on aerial photos) at several points of this chronosequence.

Figure 6. Calgary’s historic growth (1924 to 1998) and projected future footprint if growth occurs at 4.5% annually.
With a relatively affluent human population, both among young professionals and retirees, many families are choosing to live in smaller communities nested along or inside the Canadian Rockies. For some, these communities represent a year-round residence, whereas for others they offer condominiums for seasonal vacations. This trend has been fueled by the advances of electronic communications that has made telecommuting an effective and efficient lifestyle option. A good example of such a desirable tele-commuting
venue is Canmore (Figure 9): during the past 30 years, the footprint of Canmore has increased by approximately 4 times (Figure 10) and the population by over 600% (Figure 11).

Figure 9. Looking down on Canmore from Wind Ridge.

Figure 10. These two air photos of Canmore (1950 left and 1999 right) illustrate the rapid growth trajectory and the fragmentation of an important wildlife movement corridor along the Bow River valley. Issues include direct loss of bear habitat, increased human population and associated recreational pursuits that place humans in greater contact frequency with bears.

From the standpoint of grizzly bear conservation, the absolute number of people in and near grizzly bear home ranges is far more important than the loss of native habitat caused by expanding human communities. To illustrate this point, the historical and future projected human populations at three spatial scales are presented below. The populations of each of Alberta, Calgary and Canmore are all expected to grow considerably during the next half century, but greater growth (in percent) is anticipated to occur in Calgary than in Alberta, and the greatest growth (in percent) is anticipated to occur in the mountain resort community of Canmore.
Figure 11. Historical and future projected human populations at 3 spatial scales. Canmore (within current Grizzly Bear distribution), Calgary (proximal to Grizzly Bear distribution), and Alberta. Best fit lines are fitted to historical data and used to project future (2000–2050) annual growth of 3.5% (Canmore), 2.0% (Calgary), and 1.8% (Alberta).
AN EXPANDING WAVE OF RURAL RESIDENTS

With increasing appetite, Calgarians, Albertans and others are looking to build homes and reside in the foothills of the Rocky Mountains in Alberta. Located within reasonable commuting distance to Calgary, foothill communities such as Bragg Creek, Water Valley, Canmore, Millarville, are experiencing a rapid increase in the density of acreage dwellers or condominiums. This expanding wave of “rural residential” is consuming habitat previously used by grizzly bears, and placing humans and bears in much greater proximity. As acreage complexes emerge, they serve as focal points that in turn increase levels of mountain biking, fishing, hiking, trail riding, and hunting. Not surprisingly, conflict interactions between grizzly bears and humans increase in direct proportion to intensity of recreational activity (Mattson et al. 1996). Some of these unfortunate encounters will lead to the destruction of individual bears, further eroding the ability of the regional grizzly population to persist.

The Miistakis Institute of the University of Calgary has recently completed some revealing time-series evaluations of building structures within all quarter sections (0.5 x 0.5 miles) that comprise the Municipal Districts of the East Slopes of the Alberta Rockies (Rocky View, Foothills, Ranchlands, Pincher Creek, Willow Creek, and Cardston) (Duke et al. 2003). Although not all of the structures found within this study area are rural residences, most of the growth during the past 50 years can be attributed to residential development.

Whereas building structures have been growing by an average of 2.5% annually during the past 3 decades (Figure 12), much of the growth and density is clearly expanding outwards from the major urban centres and further into the foothill environs (Figure 13, Figure 14).

Figure 12. Temporal trends in number of building structures in each quarter section within the Municipal Districts of the Alberta’s East Slopes (Rockyview, Foothills, Ranchlands, Pincher Creek, Willow Creek, and Cardston). Data prepared by the Miistakis Institute.
The time-series of photos below (Figure 15) illustrate the landscape transformation that has occurred in the Bragg Creek region during the past several decades. Although the initial landscape conversions were associated primarily with agricultural cultivation, subsequent growth of acreage complexes triggered significant human population growth, and landscape fragmentation.
Figure 15. These two photographs (of approximately similar scale) of the hamlet region of Bragg Creek, one is 1950 (left) and one in 1997 (right), illustrate the growth of the community during a five decade period. In addition to the actual hamlet, much growth of rural residential complexes has occurred in the surrounding foothills landscapes surrounding Bragg Creek (see below).

Figure 16. This air photo, taken west of Bragg Creek in 1997, illustrates the fragmentation and loss of grizzly bear habitat associated with the expansion of acreage complexes. The main east-west road in this photo leads west to a popular staging area for hikers, bikers, hunters, and skiers on the border of Kananaskis Country. Some of these recreationalists will encounter grizzly bears during their recreational pursuits, and the outcome of some of these encounters will lead to the destruction of individual grizzly bears. This local effect will combine with other regional effects in a classic cumulative effects scenario decreasing grizzly bear range and increasing mortality probabilities.
EXPANDING APPETITE FOR RECREATIONAL OPPORTUNITIES

Affluent, relatively young and active, residents of Calgary, Cochrane, Canmore, and other foothill communities are increasingly looking west to the mountains to hike, mountain bike, ski, fish, hunt, or for recreational motoring (Figure 17, Figure 18). These activities can only be accommodated with an appropriate transportation network, which takes many forms (Figure 19). Much of the demand for recreation is met by the mountain landscapes in and surrounding Kananaskis Country, Canmore, and Banff; all areas that have historically provided valuable habitat for grizzly bear. Figure 20 illustrates the increasing amount of demand for these recreational and other activities in Banff National Park.

Figure 17. Although Calgary represents a relatively small portion of the overall landscape, it houses a large and growing human population that pursues a suite of recreational opportunities beyond its urban borders.

Figure 18. Trail riding is a popular and growing recreational landuse in the foothills of southwest Alberta (left). The total footprint of ski resorts has increased substantially during the past several decades.
Figure 19. The transportation network is not restricted to roads built to move commercial goods, but also takes many other forms (trails, ski runs, rivers) that serve a diversity of recreational activities.

Figure 20. Between 1990 and 2000, visitation to Banff National Park grew from 3.54 million to 4.56 million visitors, representing an average annual growth of 2.85% (Banff National Park Census data). If this rate of growth continues, visitation to Banff will increase by at least 2.25 times during the next three decades.

Although many of the visitors to Banff National Park do not venture far from their cars or the major road network, they do represent an important mortality source to grizzly bears because of bear-vehicle collisions. Furthermore, even if the percent of visitors to Banff who chose to enter the back-country remains constant, Banff will witness an approximate 225% increase in the number of people using the established trail network by 2030. A small percent of these hikers and campers will encounter grizzly bears and these encounters will increase as visitor numbers climb.
FORESTRY PRACTICES ALONG THE EAST SLOPES

Commercial forestry is conducted on portions of the public forests in southwest Alberta, but not within provincial or federal parks. Of the approximately 1.65 million hectares of forests found along the east slopes of the Rockies from the US border to the northern extent of the Red Deer River drainage basin, approximately 48% is part of the active commercial forest landbase (Bev Wilson, Alberta Natural Resources Service, personal communication). Of these commercial forest lands, an additional 31% is not eligible for logging under current regulations because of forest stands that are too close to water, too steep, or inaccessible. This means that about 33% of the total forest landscape of East Slopes region will observe some form of logging under current regulations during the next forest rotation (~100 years). Although actual harvest volumes can vary from year to year, the sustained yield harvest of softwood and hardwood is approximately 550,000 m³ and 38,000 m³, respectively.

The actions of forestry have two important, and distinctively different, effects on grizzly bears in the CRE of Alberta. First, logging has created a more heterogeneous forest landscape and increased the amount of herbaceous vegetation available as forage to grizzly bears (Figure 21, Figure 22). Similarly, the increase in young forests and herbaceous vegetation can increase the capacity of the landscape to support ungulate populations, and hence prey for grizzly bears. As long as reasonable amounts of escape cover are maintained in a managed forest landscape, the habitat effects of the forest sector can be beneficial.

Counter-acting these potentially beneficial effects of logging are the indirect consequences of the haul roads and in-block roads built by the forest sector to access and remove wood fiber (Figure 21, Figure 22). As density of these linear features increase, so does visitation by people in the industrial, hunting, recreational, and poaching sectors. As discussed in greater detail later in this report, the various human activities associated with roads are “the” key factor leading to high levels of grizzly bear mortality in much of southwest Alberta. If forestry operations and grizzly bear populations are to persist both in time and space, it will become necessary for resource managers to minimize the construction of roads and to implement some form of access management along the increasingly abundant forestry roads in the region.

Figure 21. Infra-red photo of cutblocks in Alberta illustrating increased levels of landscape heterogeneity and inblock roads. Although many of these roads are effectively reclaimed by the forest sector, some are not because they provide useful access by the forest sector for post-harvest silvicultural treatments, are used by the energy sector to access drilling sites, or are maintained by the recreational community by repeated re-use. Photo from the AME Photo Library.

Figure 22. Whereas the forest sector can increase the amount of young herbaceous vegetation and hence forage availability (left), the accompanying road networks often lead to increased levels of bear mortality. Photo from the AME Photo Library.

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OIL AND GAS EXPLORATION AND EXTRACTION

As with forestry, the energy sector harvests trees as they construct pipelines, wellsites, processing plants, and seismic lines. The resultant herbaceous vegetation can benefit grizzly bears through an increase in forage and improved ungulate habitat (Figure 23).

However, these same linear features (wellsites, roads, pipelines) also fragment the landscape and allow greater access to the landscape by humans and their activities. The very features, such as pipelines, that can provide abundant and favorable forage for grizzly bears, can also serve as an efficient means for bears to be observed and killed.

Whereas the historical well drilling trajectory in Alberta’s East Slopes has been one of exponential increase (Figure 24), declining reserves of conventional oil and natural gas are thought to bring a reduced future level of exploration for these reserves in the East Slopes of Alberta (Shad Watts, Alberta Energy, personal communication). As conventional gas reserves become exhausted, the energy sector has become increasingly interested in tapping unconventional gas reserves, which has lead to the arrival of a new member of Alberta’s hydrocarbon sector – that of coalbed methane extraction. Much remains to be learned about the distribution and recovery technologies for this new and important non-renewable resource, but it would appear likely that significant levels of exploration and extraction of coalbed methane will occur along Alberta East Slope foothill communities in coming decades.

Figure 23. An active well drilling site (left) and clearing associated with the installation of a pipeline (right). Photo from the AME Photo Library.

Figure 24. Historical pattern of wells drilling activity in the Oldman River Drainage Basin. Data provided by Alberta Energy and Utilities Board.
LIVESTOCK GRAZING IN THE FOOTHILLS

For Alberta’s provincial cattle herd of 6 million, the leased lands of the east slopes of the Rockies provide approximately 186,000 animal unit months of grazing (Mike Alexander, Alberta Environment, personal communication) (Figure 25). These lands provide important foraging opportunities for cattle, but also place livestock and grizzly bear in proximity. Over the past several decades, the expansion of livestock grazing and associated activities into the foothills displaced grizzly bear from much of their historic foothill range. Whereas the rate of forest clearing on public lands has generally declined in recent decades, deforestation of traditional grizzly bear habitat continues today in some areas (Figure 26). Whereas some ranchers remain opposed to the maintenance of grizzly bear populations on public lands used for livestock production, others have demonstrated both desire and ability to coexist with grizzly bears. One key is keeping attractants such as grain and carcasses away from bears. Another is maintaining healthy grassland ecosystems. In recent decades, stocking densities of cattle on leased foothills land have often been reduced to ensure the health of foothill rangelands.

Figure 25. The east slopes of the Rockies in southwest Alberta provide grazing opportunities for livestock. Photo from the AME Photo Library.

Figure 26. An example of deforestation of white zone crown land northwest of Bragg Creek in the 1990s for purposes of range improvement to enhance cattle stocking rates. Photo from Alberta Air Photo Library.
ROADS, ROADS, AND MORE ROADS

If there is one recurrent feature of human-dominated landscapes that is highly correlated with declining grizzly bear populations along the Rocky Mountains in North America, it is road density. Roads bring fast moving cars causing vehicular mortality to grizzly bears. Roads also bring poachers, legal hunters, and a diversity of recreationalists. Many of these roads owe their origin to the forest and energy sector, and although management plans suggest a reclamation priority, much of this linear feature network persists for lengthy periods to satisfy resource industries and a growing demand from the recreational community (Figure 27, Figure 28).

Figure 27. The commercial transportation network continues to grow in the foothills landscape of western Alberta, and it takes many diverse forms based on moving people, electricity, wood fiber, hydrocarbons, livestock, crops, and aggregate materials across the landscape.

Figure 28. Many roads built in grizzly bear habitat today are constructed by the private sector. Among these, roads associated with the forestry and energy sectors, and acreage developments, are dominant features. Photo from the AME Photo Library.
The ongoing construction of rural residences and associated acreage road networks in the foothill regions of the Alberta portion of the CRE is well illustrated in the Municipal District of Rocky View (Figure 29). As of the early 2000’s, Rocky View was home to ~11,000 acreage residents occupying ~3,600 acres. If this current acreage population were to continue to grow at 4% annually (actually a lower growth rate than has been observed in recent years), and the associated roads (both driveway and acreage common roads) required for each new acre is 200 m, then this municipality would have built ~150 new acreages and 30 km of associated road length in 2000. By 2030, though, the number of new annual acreage homes would be 490 and the associated road network would be 100 km. It has been precisely this pattern of incremental growth of rural residences and transportation networks that has contributed to the transformation of the landscape observed during the past three to four decades.

![Annual Rural Residential Trajectory for New Homes and New Acreage Roads](image)

Figure 29. Projected development trajectory for new acreages and associated road networks for the MD of Rocky View (2000 to 2030).

**CONCLUSIONS**

Grizzly bears and humans in Alberta have shared a dynamic history that has probably spanned 10,000 years. However, during the past 200 years, the distribution and abundance of grizzly bears has been radically reduced, while that of humans has dramatically increased. This grizzly bear trajectory has occurred in general because of loss of preferred habitat and specifically because of increased mortality associated with hunting, poaching, road and rail collisions, and removal of problem bears.

The CRE represents a key remaining habitat for grizzly bears in Alberta, but this landscape is experiencing a rapidly increasing anthropogenic footprint and activity level associated with a wide suite of human landuse practices. Assuming the area and intensity of activities/footprints such as hiking, fishing, mountain-biking, settlements, back-country resorts, acreages, forestry, oil and gas development and associated road and trail networks continues to increase at their forecasted trajectories, grizzly bear mortality rates will almost certainly increase.

Where no grizzly bear hunting occurs (most of Banff National Park and Kananaskis Country), the grizzly bear population in the Bow River Watershed appears to sustain itself while subjected to current mortality rates. With continued human population growth and development, maintaining current levels of mortality, even in unhunted portions of Banff Park and Kananaskis Country, will become increasingly difficult - yet is essential to prevent population decline (Garshelis et al. 2004). Within the CRE north of the Bow River current grizzly bear mortality appears to be too high to maintain current population levels (Stenhouse et al. 2003).
Maintaining the current range and populations of grizzly bears in the CRE will demand bold thinking by contemporary landscape managers, for their decisions today will largely define the future of grizzly bears in the next several decades. Ultimately, resource managers must help society recognize that there are clear trade-offs between the level and intensity of our landuse footprint and the viability of grizzly bear populations. Recognition of these trade-offs can lead to productive discussions about acceptable thresholds for such landscape variables as road density and use, back-country visitation, and habitat area and connectivity. Clear recognition of trade-offs between social, economic, and ecological indicators, such as grizzly bear populations, is key to exploring best practice options. For example, if managers can agree that mortality along roads is a key “driver” in the grizzly bear story, then the merits of access management becomes a logical “what-if” scenario to explore. Not allowing the public to travel on all roads at all times is currently a difficult landuse alternative for society to consider. However, it is a good example of the types of alternative scenarios that must be evaluated if we are to increase the likelihood of having healthy grizzly populations and the ecosystems needed to support them.

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14. DENNING
Saundi Stevens and Michael Gibeau

Vroom et al. (1980) first documented winter den ecology of grizzly bears based on locating and examining 29 completed and 18 partly excavated dens, including those from a small sample of radio-collared bears in the Cascade Valley of Banff National Park. Research beginning in the late 1970’s has shown that pregnant females are usually the first bears to den in the fall and the last emerge in the spring. Male grizzly bears are almost always the last to enter their den in fall and the first to emerge in spring. These patterns in den use vary depending on the age of the bear and the local climate. In addition to documenting timing of den entry and emergence of bears, Vroom et al. (1980) documented environmental and structural parameters of winter den sites. They did this largely by using a sample of den sites visually identified by helicopter surveys and ground searches of nearby areas. Vroom et al. (1980) acknowledged that this method might have biased their analysis, typifying dens that were most visible in open habitats.

The ESGBP has observed the nature and distribution of grizzly bear dens since the initiation of the project in 1994. In particular, research has focused on identifying den sites used by radio-collared grizzly bears. Following a sample of approximately 25 radio-collared bears to their dens each year complemented earlier research, and eliminating the possible bias for dens visible from the air. In late fall, we located den sites using aerial telemetry. The dens were then visited in the spring after the bears had moved on to spring feeding sites. Field researchers surveyed den sites of radio-collared bears opportunistically while in field for other research purposes. Therefore, of 173 den locations obtained by aerial telemetry (1994-2001) only 30 of those sites were characterized from the ground.

Over the past two decades, research on grizzly bears in the Rocky Mountains of Alberta has determined that bears spend, on average, 4.5 months of the year in or near their den sites (Vroom et al. 1980). Over the course of the ESGBP research, we documented grizzly bears entering their dens between mid-October through to the end of November. In the spring, the earliest emergence documented was mid-March and the latest was mid-May. Radio-collared females with cubs in our study had a mean emergence date of May 12 compared to April 16 for adult males.

Grizzly bears in the eastern slopes of the Rockies almost always excavate their own dens but, on occasion, they will use a natural chamber such as a cave. One radio-collared female with three cubs denned in the same natural rock cave for three consecutive winters. As previously reported (Vroom et al. 1980) grizzly bears often showed a preference for a particular denning area. On five occasions, old den sites were found within a few hundred meters of active den sites. This could also indicate that offspring will return to where they and their mother denned in earlier years. Old dens were characterized by the amount of vegetation growth in the pile of tailings.

Dens are usually dug horizontally into slopes, where the bear heaves an incredible amount of rock and rubble out between its legs and down the mountainside. Each den contains a tunnel that opens up into a chamber, the chamber being larger in height and width than the tunnel. The chamber is cup-shaped and often lined with fir boughs, grass or small twigs. We did not document any grizzly bear re-using its excavated den over consecutive years. Most often it seemed the den ceiling collapsed after the soil thawed in the spring, and therefore deemed the den unusable for the next winter. For this reason too, many of the dens we visited could not be reliably characterized in our analysis because of their poor condition.

We adopted Vroom et al.’s (1980) list of standardized measurements of den site parameters. These measurements were taken at each site visit so that den characteristics could be compared amongst our sample and with results from Vroom et al. (1980). We found the average total length of dens, measured from the entrance to the back of the den chamber, is 2m. The average width of the den entrance is 63.5cm and the average height of the entrance is 63cm. The chamber of the den is usually just large enough for the bear(s) to curl up and turn about. The den chambers we surveyed ranged between 0.95m and 1.75m wide with an average chamber height of 98cm.

Similar to Vroom et al. (1980), we also described the environmental parameters (elevation, slope aspect and slope angle) of each den site. Estimates were made of the relative abundance of different species within tree, shrub and herbaceous layers near the den. We did not do any detailed soil structure/classification analysis.
All dens we surveyed were found in the upper sub-alpine at elevations between 2012m (6700ft) and 2432m (8100ft) or an average of 2253m (7500ft). Research in the late 1970’s documented an average elevation of 2280m (7592ft) (Vroom et al. 1980). Vroom et al. (1980) explored thermal inversion as an environmental variable relating to the altitude of den sites. All of our grizzly bear dens surveyed were located at altitudes where preliminary data suggests that thermal inversion is a prevalent phenomenon. Extreme temperatures and heavy precipitation influence the sub alpine region (Vroom et al. 1980). At these elevations the forest becomes diffused with glade openings and small, scattered colonies of dwarf krummholz. The tree species we documented in the den areas were subalpine fir, subalpine larch, and Engelmann spruce.

The most widespread plant associations of den habitats were grouseberry, heather, false azalea and rhododendron. Some dens were at the top or near the edge of avalanche tracks cutting into the forest. Tall herb-grass meadows on southwesterly slopes, and willows on northeasterly slopes dominated these avalanche areas. We documented 15 dens buttressing trees or shrub root complexes. 14 dens were found in small glade openings or herb/meadow slopes and 1 den in a natural rock cave.

Bears often dig dens with a particular slope orientation or aspect. Studies completed in the late 1970’s revealed the aspects of 36 of 47 dens and partial dens ranged between a compass orientation of 45°(NE) and 112.5°(ESE) (Vroom et al. 1980). ESGBP den surveys found no preferred aspect as they varied widely between 80° (NEE) and 295° (WNW). Knowing that the prevalent winds in this region are traditionally out of the west, we would have expected more den aspects to be facing eastward, leeward of the west wind. However, the compass orientation of this lee may vary from place to place even within the same locality, according to topographic and microclimatic factors. We presume that local climate and micro-terrain is more a factor for den site selection than a specific aspect/orientation. Bears usually try to dig their dens where deep snow will accumulate and where the entrance is sheltered from strong winds. A thick blanket of snow over the entrance of the den provides a layer of insulation for the long winter. A small rock outcrop or terrain feature in proximity of the den entrance can theoretically accommodate snow accumulation on any aspect.

Grizzly bears do seem to be specific about the slope angle on which they dig their den. The mean slope angle for dens we investigated was 33 degrees. All dens were on slopes greater than 26 degrees and none were on slopes greater than 39 degrees. Vroom et al. (1980) documented their dens also having been dug into slopes averaging 33 degrees. Studies have shown that this narrow range of slope angle is steep enough that there is plenty of soil or rock overhead to form a nice thick den roof that is unlikely to collapse during the winter yet is still an angle shallow enough for the den opening to be covered by a heavy blanket of snow (Vroom et al. 1980).

Overall, our research on grizzly bear den sites contributes additional data to help substantiate some of the earlier knowledge of the physical characteristics common to den sites in the Rocky Mountains. This information, especially when combined with results from previous studies, provides for a comprehensive understanding of the nature of suitable denning habitat for grizzly bears in the Central Rockies Ecosystem.

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CHAPTER 15

MANAGEMENT RECOMMENDATIONS: EASTERN SLOPES GRIZZLY BEAR PROJECT FINAL REPORT
15. MANAGEMENT RECOMMENDATIONS: EASTERN SLOPES GRIZZLY BEAR PROJECT FINAL REPORT

Please see pages vii to xviii of the Summary for an outlined, short version of this chapter. Also note that we recommend priority 1 (P1) for implementation within 2 years, and priority 2 (P2) for implementation within 5 years.

1. DEMOGRAPHY AND MONITORING

*Goal: To achieve a sustainable human-caused grizzly bear survival/mortality rate throughout the Central Rockies Ecosystem (CRE) that is scientifically documented by collecting adequate data, with an established level of acceptable risk that supports a high probability for the long-term survival of grizzly bears in the CRE.*

1a. Establish science-based survival (mortality) rate targets for adult female bears that would have a high probability of supporting population growth or maintenance (lambda ≥1) for each grizzly bear population management unit in the CRE. (P1)

We congratulate managers in the Bow River watershed (BRW) portion of the CRE for achieving a 95% survival rate (5% mortality rate), 1994–2002, for adult female grizzly bears (Garshelis et al. 2005). This high survival was key to a highly probable positive population growth rate (λ) during this time period. A survival rate of 91% for the BRW should prevent population decline, although this target would be risky, as it does not consider either environmental stochasticity or sampling error. A safer target and the one we recommend would be to maintain the 95% survival rate for adult females that we documented (Garshelis et al. 2005).

This adult female survival rate also represents the best target, until new research demonstrates otherwise, for the larger portion of the CRE and population management units that exist beyond the BRW. From a biological perspective population management units would be based on bear populations that have free genetic exchange within a unit and much less exchange with other units. Such population units would be mostly “closed.” The extent of gene flow between units can be determined by collecting DNA samples (Proctor 2003, Proctor and Paetkau 2004). Jurisdictional boundaries between federal and provincial areas will complicate integrated management of biologically-based population units.

Maintaining a high rate of grizzly bear survival will likely become more difficult in the future, as mortality data from the BRW, 2003–2004, suggests (Chapter 5.2, this report). Vision, funding, personnel, public support and commitment will be needed to prevent an increased human-caused mortality rate and population decline and to know if this is occurring.

Grizzly bears in the BRW had a reproductive rate that was at the low extreme of all populations studied in North America (Garshelis et al. 2005). It is doubtful, at least in the short term, that this rate can be raised. Therefore management efforts to maintain high demographic vigor (λ) should be focused on survival. Given what appears to be a low population density, and hence abundance in the BRW (Chapter 5.3, this report), achieving high survival, especially of adult females, is necessary for population persistence. Male mortality has little direct effect on population growth, unless breeding is affected or unless losses of males affect the mortality rate of females.

1b. Monitor survival/mortality rate and reproduction in the Bow River Watershed. (P1)

We recommend monitoring survival/mortality and reproductive rate for adult female grizzly bears in the BRW. This rate should be evaluated against target values. This approach would be desirable in the BRW because of the large amount of human use and development and therefore the chance of unsustainable mortality and the need to know if this is occurring. Scientifically designed research that includes capturing, radiomarking and monitoring a representative sample of grizzly bears would provide the most reliable
assessment of survival, reproduction and growth rate. This approach also allows for informed interventions and helps to set demographic targets. Without having taken this approach we would not have discovered the high survival rate and low reproductive output in the BRW, 1994–2002.

To assess whether the goal of maintaining a non-declining grizzly bear population is being met, we recommend that managers continue to monitor survival and reproduction in the BRW using a sample of radiomarked females similar to ours (~15 bears/year; Garshelis et al. 2005). Maintaining such a sample of radiomarked grizzly bears for multiple years is the most scientifically defensible means of monitoring survival and reproduction. Since this is an expensive and invasive approach it should only be used when information regarding grizzly bear population dynamics is judged to be critical as in the BRW and the Yellowstone Ecosystem in the United States (Schwartz et al. In press).

Survival could also be crudely monitored without radiomarking, just by counting known dead grizzly bears (Garshelis et al. 2005). Benn and Herrero (2002) did this for Banff National Park while we conducted the ESGBP telemetry study. They documented a decline in mortality, concomitant with dramatically improved human food and garbage management and more protective management policies. Using their data as a baseline representing positive population growth, management authorities in Banff National Park could strive to ensure that total mortality did not increase beyond this (Garshelis et al. 2005). Radiotelemetry, though, would be a more reliable means of obtaining mortality data and is the method we recommend for the BRW. Maintaining a representative, radiomarked sample such as we had would also allow for monitoring of reproduction, population growth ($\lambda$), and important aspects of movements, landscape use and interactions with humans. Longitudinal study of radiomarked bears will not give a point estimate of population size.

1c. Develop and apply non-invasive DNA “capture-recapture” designs to calculate and monitor relative abundance, derive population estimates against which to evaluate human-caused mortality, and as one means of documenting distribution changes. (P1)

For the majority of the CRE, where longitudinal study of radiomarked bears is neither desirable nor feasible some means is needed to scientifically estimate population size and mortality rates for different management units. Without radiomarked bears only human-caused mortality can be estimated. In the BRW 1994–2002, known, human-caused mortality was 75% and 86% of adult female and adult male mortality, respectively. Based on this, total mortality rate could be estimated but one would have to assume these figures were valid estimates for other population units. This lack of precision would have to be taken into account in managing human-caused mortality. Acceptable human-caused mortality rates for a given management unit should be a percentage of the most scientifically defensible population estimate. The desirable human-caused mortality rate should be one that, combined with the natural mortality rate, supports a high probability of population growth or maintenance. Unless individual animals are being monitored over time, 45–51% of grizzly bear mortality has been found to be unreported (McLellan et al. 1999). This needs to be taken into account in setting targets for known, human-caused mortality.

We recommend continuing to develop and use DNA capture-recapture sampling methods that have revolutionized researchers’ ability to estimate relative abundance and population size of grizzly bears, and to document distribution (Poole et al. 2001, Boulanger and McLellan 2001, Boulanger et al. 2002, 2004a,b). There are, however, important issues to be resolved, especially regarding use of DNA capture-recapture methods for deriving population estimates. The primary unresolved issues relate to choosing a sampling grid design and number of hair-capture session repetitions that potentially would yield a sufficiently robust and precise population estimate (Boulanger 2004a, b). In British Columbia, population estimates with coefficients of variation of less than 20% have been obtained with intensive sampling designs (Poole et al. 2001, Boulanger et al. 2002). Issues regarding closure (especially when radiocollared animals are not also part of the study), possible heterogeneity of the samples related to differences between males and females, age, and individuality, remain to be fully resolved (Boulanger et al. 2004a, 2004b). Also specific to the CRE, there is significant use of electric fences. Bears that have experienced electric fences may be less likely to go under or over knee-high barbed wire that is intended for hair collection. This could be another source of
sampling bias. However, DNA capture-recapture designs are promising and should be regularly and carefully evaluated and used in the CRE. If they can be demonstrated to provide the demographic information needed to sustainably manage grizzly bears then this could eliminate most of the need to capture and radio-collar bears. The Province of Alberta is currently developing, using and evaluating DNA capture-recapture research designs in the Alberta portions of the CRE and elsewhere (personal communication: Gordon Stenhouse, Foothills Model Forest, Hinton, Alberta). We also recommend that habitat-based density models be developed to be able to extrapolate density from areas where DNA capture-recapture population estimates are available to ecologically similar, but unstudied, other areas. This would allow for habitat-based population estimates, and combined with data on human-caused mortality, estimation of sustainable mortality rates.

DNA sampling is also the method of choice for determining grizzly bear distribution. We recommend that it be used along with other means to assess whether potential grizzly bear habitat is occupied.

1d. Use annual counts of females with cubs as a coarse index of population trend. (P2)
Annual counts of the number of females with cubs of the year have been used in the Greater Yellowstone Area to derive a minimum population estimate, and also as an index whose year to year direction reflects population trends (Knight et al. 1995, Haroldson 2004). From the minimum population estimate derived from analyzing annual counts of females with cubs, annual allowable human-caused female mortality has been derived (Haroldson 2004). The ESGBP recorded annual counts of females with cubs of the year (Gibeau and Stevens 2003). However, since visibility is less in the BRW versus the Yellowstone Area, we only recommend this method in the BRW for coarse trend monitoring.

1e. Have periodic scientific peer review and inform the public regarding the scientific basis for grizzly bear population estimates. (P1)
Because grizzly bears in the CRE are secretive, hard to see, occur at low population densities, and have large home ranges it will always be difficult to derive population estimates. However, such estimates are essential to determine annual allowable total and human-caused mortality. We recommend that the science used to make such estimates be explicit, subject to periodic scientific peer review, and be made public.

1f. Given the extremely low reproductive output of grizzly bears studied in the Bow River watershed, use research to better understand the reasons. (P2)
Our demographic research showed that grizzly bears in the BRW and probably the rest of the Alberta portion of the CRE have little resilience, the ability to recover abundance after numerical decline (Weaver et al. 1996, Garshelis et al. 2005). A low reproductive rate and population density determine this. Our research has not clearly revealed the cause of the extremely low reproduction. Extensive research has demonstrated that reproduction is fundamentally controlled by nutrition and especially by the availability of high energy foods (Rogers 1976, Stringham 1990, Ferguson and McLoughlin 2000, Chapter 8 this report). It is widely believed that decades of fire suppression have made habitat less productive for species such as grizzly bears (Hamer and Herrero 1987, Hamer 1996, 1999). This is because many of the high energy foods found in the CRE, such as berries and ungulates, become abundant post-fire and then decline with succession. Research regarding high-energy grizzly bear foods such as ungulates and berries should be carried out and focused on better understanding their role in nutrition and reproduction. A negative influence of humans and development on habitat use may also be depressing reproduction (Chapters 11 and 12, this report).

1g. Continue research regarding body condition and reproductive hormones. (P2)
In an effort to seek potential explanations for low cub production by Eastern Slopes grizzly bears, a comparison of select health parameters was made between Eastern Slopes and Foothills Model Forest (FMF) Grizzly Bear Project bears. The parameters considered were body condition as a reflection of nutrition and reproductive hormone levels as a reflection of reproductive function. The working hypothesis was that reduced reproductive output in ESGBP grizzly bears was a result of low energy uptake causing diminished reproductive function (Chapter 8, this report).
Results from a comparison of body condition and reproductive hormone concentrations between ESGBP and FMF bears were consistent with the hypothesis that reduced reproductive output (long interval between litters and low reproductive rate) in Eastern Slopes grizzly bears was a result of low energy uptake (especially in males) causing diminished reproductive function. Converging results, supporting the idea of low energy uptake, came from our preliminary study of grizzly bear diet using stable isotopes (Chapter 8, this report). We recommend continuing these lines of research to try to better understand the low reproductive output in Eastern Slopes grizzly bears.

2. MORTALITY: RECORDING, UNDERSTANDING AND MANAGING

Goal: To document, evaluate, understand and sustainably manage grizzly bear mortality.

2a. Document, analyze and report annually on grizzly bear mortality in the Central Rockies Ecosystem. (P1)

One of many reasons for recording and analyzing grizzly bear mortality rates in the CRE is because most mortality is human-caused and therefore can be influenced by management actions (Benn 1998, Benn and Herrero 2002, Garshelis et al. 2005, Chapter 6 this report). Known, human-caused grizzly bear mortality has been regularly recorded in all jurisdictions. However, in the past, record keeping has been in different formats, there have been significant errors of omission and analysis has been infrequent (Benn 1998, Benn and Herrero 2002). Given the fundamental role that survival has in grizzly bear population persistence, records of mortalities should be thorough and precise throughout the CRE. Biological and human-related important details should be recorded in exactly the same manner within each jurisdiction. This would facilitate CRE-wide annual assessment and reporting such as is done for the Greater Yellowstone Ecosystem (see Haroldson 2003, p. 28, Table 13 for an excellent example. This is reproduced in Appendix 1.) We recommend that Parks Canada, Alberta, and British Columbia meet and decide how best to develop and manage this database and annual analysis. Annual reporting should be a conjoint effort. This should be used to inform researchers, agencies, industry and the public.

Accurate biological data needs to be supplemented with human-related information regarding cause of death, location, distance to access, condition of access at time of mortality, mode of travel of person responsible for removal of bear, presence or absence of human food attractants and natural foods, and what role if any human artifacts and behavior played in the mortality (Benn 1998, Benn and Herrero 2002).

2b. Develop programs to be able to manage each significant source of grizzly bear mortality in a responsive way with annual reports and annual review of mortality management programs and their success related to cause-specific mortality. (P1)

The adverse effect that unsustainable, human-caused mortality has on grizzly bear populations is often developed through the cumulative effects of many factors. Human-caused grizzly bear mortalities in the BRW are associated with a variety of human activities (Benn 1998, Benn and Herrero 2002, Chapter 6 this report). Human activities associated with mortalities are influenced by landscape management policies such as grizzly bear and ungulate hunting, human food and garbage management, recreational developments and associated activities, and access. Science can be used to derive estimates of sustainable human-caused mortality rates for management units. Achieving these mortality rate targets involves influencing people and their actions in grizzly bear habitat.

Given that increased development and human activities will increase contact with grizzly bears (Chapter 13, this report), we will have to become better at managing potentially lethal human actions for the bears to survive at sustainable rates. Human behavior will have to change to maintain high survival rates for grizzly bears as more people and development occupy the landscape. Changing human behavior will likely involve decreasing individual rights and privileges that are currently enjoyed related to landscape development and unrestricted use (McLellan 1998). Managing the impacts of individuals may prove to be more difficult than managing impacts of industry (McLellan 1998).
Specific programs should be developed to help manage each major source of human-caused grizzly bear mortality so as to maintain or bring overall human-caused mortality to sustainable target levels. Our research shows major human dimensions associated with grizzly bear mortalities are: grizzly bear and ungulate hunting, recreation, and problem wildlife (addressed primarily by human food, garbage, and livestock management), First Nations (need to develop dialogue), high speed highways and railways, and research on grizzly bears (Benn 1998, Chapters 6.3 and 6.4 this report).

2c. Use understanding of spatial aspects of grizzly bear mortality in the CRE for input into planning human activities that have a significant grizzly bear mortality probability so as not to exceed the established human-caused, mortality rate limits for each management unit. (P2)

Knowledge of the characteristics of locations where human-caused female grizzly bear mortalities have been concentrated may be used to inform land and grizzly bear management decisions (Chapter 6.6, this report). Managers may choose to carefully monitor mortalities in these areas and in some cases take steps to decrease such mortalities. Lake Louise is one such area where steps are being taken to decrease the high level of human-caused mortalities of female grizzly bears (Benn 1998, Benn and Herrero 2002, Nielsen et al. 2004).

Access management is a key issue in planning for grizzly bear persistence. Grizzly bear mortalities cluster near motorized access (Benn 1998, Benn and Herrero 2002, Nielsen et al. 2004, Chapter 6.4 this report). The low levels of habitat security (Chapter 12, this report) for grizzly bears in the CRE should be addressed through access management. In portions of the CRE where grizzly bear hunting exists and there is area concentrated mortality (Chapter 6.6, this report), specific restrictions such as access control, could be used to achieve human-caused female mortality rates that would support population growth or maintenance. The most accepted approach to manage access to provide for grizzly bear security is to apply open motorized road-density standards.

As would be expected, landscape attributes relating to human use, such as roads, trails, and terrain, correlated well with the locations of human-caused grizzly bear mortalities (Benn 1998, Nielsen et al. 2004). Spatial mortality models, like those presented in this report, can be used as a basis for management of humans in grizzly bear habitat and the identification of potential restoration (road access control or deactivation) sites. Moreover, incorporation of risk models with existing animal occurrence models (e.g., Nielsen et al. 2002, 2003) may prove useful for assessments of population viability (Boyce and McDonald 1999) and attractive sink dynamics (Delibes et al. 2001, Naves et al. 2003). We suggest that risk models be integrated with habitat models for identifying key habitat sinks and secure areas for active management and protection respectively.

3. HABITAT: DISTRIBUTION, SELECTION, SECURITY, CONNECTIVITY

Goal: To define and implement habitat standards that would support grizzly bear persistence.

3a. Using the best available data on landscape selection by especially female grizzly bears, work toward CRE-wide identification and protection of grizzly bear habitat. (P2)

If too many bears are dying in a management unit to support population growth or maintenance then managers often can lower mortality rates through management actions such as cessation of grizzly bear hunting, improved management of ungulate hunting, better recreational management, or better management of people’s food and garbage. Population recovery should occur provided that carrying capacity has not been lowered by habitat loss. Habitats are usually difficult or impossible to rehabilitate following development, especially of permanent facilities and other infrastructure. Yet habitat is fundamental to supporting any animal population.

ESGBP researchers have developed models representing habitat selection at coarse and fine scales within the CRE (Chapter 10, this report). We have shown that “scale-dependent” habitat selection occurs and that grizzly bears simultaneously select for components of habitat at several different scales. A case can be made for giving extra protection to habitats that grizzly bears select, especially habitats selected by females. We
recommend this be done based on our research findings. To assure that selection has been for productive habitats, reproduction and survival in these areas could be monitored.

In applying seasonal resource selection functions to the eastern slopes landscape, we identified 4 geographic areas that had a concentration of high probability of adult female occurrence and also had a relatively high density of human-caused grizzly bear mortalities (Chapters 6.6, and 10.3, this report). These areas were: 1) around Lake Louise, 2) from the Red Deer River/Ya Ha Tinda area, south to and including the Burnt Timber drainage, 3) around Banff townsite, and 4) along the Canmore/Bow River corridor as far east as the Kananaskis River drainage and the Old Fort Creek drainage, and extending south to include the Wind Valley and the Evan-Thomas Recreation Area. We also identified numerous smaller pockets with high probability of female grizzly occurrence distributed throughout the study area but especially south of the Trans Canada Highway. Each of these 4 areas, which had a concentration of high probability of adult female use and significant human-caused mortality density, is a candidate for management that will allow for grizzly bear habitat use with minimal human-caused mortality risk. This will be challenging to achieve because of extensive human use in these areas.

3b. Using the best available science establish habitat security targets that would support human-caused mortality rate goals. (P2)

How much habitat should be “protected” to support grizzly bears is a fundamental question. Grizzly bear needs are only one factor entering into land use planning decisions. However, land planners cannot ignore grizzly bear needs if the bears are to persist. Grizzly bears need security. This means having opportunity to live in areas where mortalities do not exceed a sustainable level. To attain this will require managing the landscape where grizzly bears live such that the frequency and potential lethality of encounters with humans yields a sustainable rate of grizzly bear mortality (Mattson et al. 1996). This entails managing human use, access and potential lethality, and monitoring human-caused mortality rates for grizzly bears.

For each jurisdiction in the CRE we calculated the percentage of the productive landscape that had undisturbed (without roads or trails) and connected minimum size units of 9 km², the mean size of an adult female's daily foraging area (Gibeau et al. 2001, Chapter 12 this report). The percent of productive land base where adult female grizzly bears have a low probability of encountering people (secure) depends on the amount of productive land available to a bear and the extent of human influence on that land. British Columbia provincial lands had the largest percentage of secure habitat (50%), followed by Alberta provincial lands and national parks with 43% secure habitat in both, and Kananaskis Country with 36%. None of these areas met the current target level of 68% considered to be adequate security set by the US Department of Agriculture Forest Service in the Northern Continental Divide grizzly bear ecosystem in northwest Montana (US Department of Agriculture Forest Service 1995).

We recommend management intervention throughout the CRE, primarily access management, to increase secure habitat to 68% with priority being given to habitat most selected for by females and where mortality has been concentrated, such as nearby Lake Louise developments and other areas we have identified (Chapters 6.3, 6.5, and 6.6, this report). The bottom line is maintaining a high rate (≥91-95%) of adult female survival. We caution that there can be decade long time lags between habitat changes and detectable population effects (Doak 1995). Maintaining low human-caused mortality rates can be expensive as it may require thousands of hours of professional work to try to teach individual female grizzly bears that being near certain developments is not good for them. An alternate approach would be to provide female grizzly bears with greater security. Monitoring changes in grizzly bear habitat security over time is a useful indicator of human influence on land.
3c. Maintain, restore or mimic ecological processes in order to recreate plant and animal communities that are more similar to those grizzly bears experienced in the CRE when First Nation peoples were the only humans. (P2)

Grizzly bears and other animals in the CRE live primarily in mountainous forested environments dominated by coniferous trees. Until about 125 years ago fire was the primary natural disturbance influencing the structure and composition of such plant communities (White 1985). Animals and plants co-evolved to live with fire. Fire created vegetation resources for certain animals. Grizzly bears in the CRE forage extensively on critical, high caloric density foods such as berries, ungulates and ants in the early seral stages after fire (Hamer and Herrero 1987, Hamer 1996, 1999). Wildfire suppression has been extensive in the CRE. In the national parks a combination of wildfire (in Kootenay National Park) and prescribed burns (Banff National Park) is being used to allow or mimic fire’s role in structuring plant communities. In most British Columbia and Alberta lands that are part of the CRE the forest is harvested. While this creates early seral stage vegetation it may also negatively influence cover (Oldershaw 2001). The major negative factor for grizzly bears related to forest harvest is increased human vehicular access and related increased grizzly bear mortality risk (Benn 1998, Chapter 6.4 this report).

Performance criteria to measure the success of ecological restoration are challenging to define. We recommend that where possible, managers allow for or mimic effects of natural fire regimes within landscape units. Target values should represent the historic fire cycle and approximate proportions of different seral stages associated with those cycles.

While ecological restoration can create the habitat needed to support grizzly bears and other species that co-evolved with fire there will be many human elements in the CRE landscape that were not part of historic ecosystems. We cautiously support human-caused environmental changes such as limited developments in habitats that provide few resources for grizzly bears or other sensitive species as long as such developments can be demonstrated to not adversely affect ecological restoration or sensitive species.

3d. Apply both coarse and fine scale selection models to landscape management to insure that habitat important to female grizzly bears is conserved. Also, support the Integrated Decision Tree Approach for habitat mapping. (P2)

ESGBP models that showed selection for greenness are useful as a coarse habitat management tool (Chapter 10, this report). Land managers can monitor across decades broad changes in greenness and human activities in grizzly bear security areas that have high greenness values. Loss of greenness could be used as an early-warning signal to precipitate management action or habitat enhancement. Models based on finer scale vegetation patterns (Chapter 10.3, this report) provide ecological correlates with bear presence, thereby allowing for active management of specific ecological attributes, levels of human use in important habitats, or other actions identified as necessary. We recommend both coarse and fine scale management approaches to ensure habitat used by female grizzly bears is conserved.

We also recommend newer habitat mapping techniques such as the Integrated Decision Tree Approach (IDTA) that is currently being used by Alberta Sustainable Resource Development (Franklin et al. 2001). This technique has the potential to significantly improve habitat mapping resolution and precision.

3e. Begin to systematically restore grizzly bear habitat in the CRE. (P2)

The number of humans and our footprint in the CRE will continue to increase (Chapter 13, this report). Therefore we must balance human activity with acceptable grizzly bear mortality rate limits to have a high probability of population persistence. To do this the ESGBP Population and Habitat Viability Workshop recommended restoration of grizzly bear habitat at a rate of 2% annually until security and survival targets are met for the CRE (Chapters 5.1, 6.4, 12, this report). Restoration should focus on managing access, primarily by seasonally or permanently closing and possibly reclaiming motorized access routes currently located in productive habitat. The ESGBP supports this PHVA workshop recommendation. We realize that industrial and recreation uses of areas considered for restoration will have to be considered.
3f. Establish and apply targets for grizzly bear distribution, habitat connectivity and fragmentation. (P2)
In the Greater Yellowstone Area one management goal aims for a condition in which grizzly bear occurrence is continually distributed throughout available habitat (Pyare et al. 2004). We recommend this goal for grizzly bear habitat in the CRE. Success could be monitored by periodic DNA (through hair and scat collection) and other sign of occurrence monitoring (please see recommendation 1c). A primary requisite to attain this goal is the prevention of habitat fragmentation that may preclude grizzly bears from dispersing freely throughout potential habitat. Habitat fragmentation has been extensive in the CRE (Chapters 7 and 12, this report). A primary human-caused barrier to grizzly bear movement in the CRE appears to be the Trans Canada Highway. Genetic connectivity across the TCH is mediated by male movement but demographic connectivity is fractured because female movement is limited. (Chapter 7 this report, Proctor and Paetkau 2004). Considering the peninsular shape of the remaining distribution of grizzly bears in southwestern Canada, we recommend that the long-term fragmentation potential from the major east-west highways such as the TCH be mitigated by creating wildlife crossing structures aimed at enabling freer female movements. Parks Canada in Banff National Park has pioneered construction and study of crossing structures on the Trans Canada Highway (Clevenger 2003). Human use around crossing structures must also be minimized to encourage grizzly bear use. Effectiveness of restoration efforts can be measured using the same genetic tools used to document fragmentation (Chapter 7, this report), and by deployment of GPS radio monitoring.

4. BEAR-HUMAN CONFLICT: AVOIDING AND MANAGING

Goal: To work toward minimizing human-grizzly bear conflict and to provide for safety for grizzly bears and humans.

4a. Develop and enforce regulations related to human food and garbage attractants throughout the CRE. Encourage public involvement using the bear smart community model and other community involvement approaches. (P2)
Probably the single most important contributor to grizzly bear and human conflict is the attraction of our foods and garbage (Benn 1998, Herrero and Higgins 2003). Almost anything edible by humans or our domestic animals, or even residues of cooking or eating, may attract a bear and result eventually in the bear being killed or removed. The national parks, most provincial parks, and the town of Canmore have adopted strong regulations and effective garbage storage technology to minimize attracting bears. We recommend communities and households throughout the CRE be encouraged to implement similar programs that focus on management of foods and garbage that attracts bears.

4b. Maintain and evaluate aversive conditioning programs, especially for female grizzly bears. Consider alternatives that may be more cost effective. (P1)
In the CRE most habituation of grizzly bears increases mortality risk and is therefore unacceptable (Herrero et al. 2005). This is true even if the bears are not human food-conditioned. Aversive conditioning of habituated females has been fundamental in keeping them away from areas where they could get in to trouble such as roadsides and campgrounds. In the BRW the apparent success of aversive conditioning has underlain the achievement of a high adult female survival rate (Benn and Herrero 2002, Garshelis et al. 2005). Aversive conditioning, which is a tool for training individual grizzly bears, has required hundreds or even thousands of around-the-clock hours from professional staff (pers. comm. H. Morrison, Park Warden, Lake Louise, Banff National Park). In developed landscapes with mortality risk, aversive conditioning is expensive yet essential in order to achieve high survival of adult female grizzly bears. One dimension of its success can be gauged by monitoring female survival rates. Another is by monitoring the costs of such programs. We recommend continued funding for implementing and evaluating such programs.

We also recommend evaluation of habitat management, seasonal use restrictions and other approaches as potentially more cost effective means of addressing the problem of potential habituation.
4c. Develop integrated CRE-wide monitoring of grizzly bear-human conflict to serve as a basis for corrective management actions. Report results yearly. Analyze every 5 years. (P1)
The success of human food and garbage management and all grizzly bear-human conflict management should be monitored by keeping and each year reporting records of bear-human conflict and related human-caused mortalities throughout the CRE. A common format for documenting conflict should be adopted by all jurisdictions in the CRE and integrated annual reporting should occur. This is discussed in more detail in recommendations 2a, 2b and 5a.

4d. Inform the public regarding grizzly bear activity in high human use areas. Continue with periodic use restrictions related to human safety or grizzly bear needs. Continue to experiment with removing natural attractants such as wild berries from high human use areas. (P1)
There are low rates of grizzly bear-inflicted injury to people in the CRE (Herrero and Higgins 1999, 2003). This has been achieved primarily by isolating people’s food and garbage from grizzly bears and informing the interested public regarding safety around bears. Despite such efforts there have been bear-inflicted deaths and serious injuries. Informing the public about grizzly bear activity in high human use areas is basic, as are periodic use restrictions for areas where the nature of grizzly bear activity either creates unacceptable potential danger to humans, or where the bears need seasonal access to resources such as berries or an elk carcass. Such practices should continue, with success being measured by a paucity of grizzly bear-inflicted human injuries and low bear-human conflict frequency.

Landscape managers in the Bow Valley have developed and tested various means of removing natural grizzly bear attractants such as Buffaloberry (Shepherdia canadensis) from high human use areas (personal communication: Steve Donelon, Alberta Community Development, Canmore, Alberta). This approach, provided that habitat restoration elsewhere results in no net loss of habitat, should contribute to human and grizzly bear safety. We recommend continuing to develop and evaluate this approach.

4e. Continue to monitor human use and to document its relationship with grizzly bear landscape use and mortality probability. (P2)
The ESGBP has conducted one of the most extensive studies of the effects of human developments and activities on grizzly bears (Gibeau 2000, Gibeau et al. 2001, 2002, Chapters 11 and 12 this report). Results have informed management decisions, especially in the Lake Louise area. However, human land use patterns and their intensity change over time, especially with changes in landscape development such as near Canmore. Monitoring human use in selected areas where there are radiomarked grizzly bears can provide insights regarding grizzly bear response to elements of human use and landscape features (Donelon 2004). This understanding can contribute to more informed management decisions. We recommend continuing research regarding human use and grizzly bear landscape use and mortality probability.

5. INTERAGENCY COORDINATION AND COOPERATION
Goal: To support agencies working together toward coordinated, integrated data collection related to grizzly bear research and management. At the same time to recognize agency jurisdictional autonomy.

5a. Work toward coordinated, integrated data collection and grizzly bear management, yet retain jurisdictional autonomy. (P1)
Many grizzly bears in the CRE spend time in several different management jurisdictions (Chapter 9, this report). This is because they have large home ranges, especially in the Alberta, eastern portion, of the CRE. This results in portions of populations being shared between management jurisdictions. The long-term viability of grizzly bears in any management unit is enhanced, and perhaps depends upon, grizzly bear survival rates in adjacent units. While population estimates for the CRE as a whole lack precision, the ESGBP Population and Habitat Viability Workshop estimated 175 grizzly bears in the Alberta portion of the CRE and 276 in the BC portion for a total estimate of 451 (Herrero et al. 2000: p.38).
To monitor the status of grizzly bears in the CRE and different population management units within it, we recommended all jurisdictions adopt a common format for recording mortality and grizzly bear-human conflict. This common format would allow for CRE-wide assessment of mortality and conflicts (see recommendations 2a and 2b). It would help to identify actions needed to address problems and could serve as a basis for dialogue between agencies. This has been done and is successful for quantitatively tracking different sources of bear-human conflict, knowing where to place management priorities, and being able to evaluate problems within and between jurisdictions in the Greater Yellowstone Area (Gunther et al. 2004).

Coordinated and integrated management by current jurisdictions was recommended after past assessments of grizzly bear management in the CRE (Dueck 1990) and the national parks (Herrero 1994). Under this system, each jurisdiction would continue to maintain its unique management programs including forestry and hunting outside of national parks, and protection within. The success of conserving grizzly bears in various management units in the CRE could be measured by monitoring human-caused mortality rates for adult female grizzly bears, and comparing these rates to ones predicted to sustain population maintenance or growth.

Either Parks Canada, Alberta, or British Columbia could take the lead toward more integrated data collection and analysis. Wherever leadership emerges, annual reporting would have to be approved and participated in by all jurisdictions for widespread credibility and to ensure respect for individual agency mandates.

Perhaps ideally there would be a high level, integrated, interagency management team that set coordinated policy for grizzly bear persistence, yet respected individual jurisdictions throughout the region. This has been the function of the Interagency Grizzly Bear Committee (IGBC) responsible for overseeing grizzly bear recovery in the Greater Yellowstone Area. It has been effective in directing and accomplishing demographic recovery.

5b. The CRE should remain as one geographic area for interagency coordination related to grizzly bear management. (P1)

DNA sampling of individual grizzly bears has been used to develop concepts of population units in southern Alberta (Proctor and Paetkau 2004) and British Columbia (Proctor 2003). The CRE landscape bounds grizzly bears along its human-dominated eastern flank, Alberta’s prairie, and its human-dominated western flank, the Columbia Valley of BC. However, its north and south boundaries are watersheds that filter but don’t restrict gene flow (Herrero et al. 2000, Proctor and Paetkau 2004). North-south demographic isolation, mediated by conservative dispersal by female grizzly bears (McLellan and Hovey 2001) in response to highways, is occurring in the CRE as a result of the Trans Canada Highway, and Highway 11 (Proctor and Paetkau 2004).

Defining management units along genetic lines, except where the units are fully isolated, will inevitably involve choice regarding how much isolation is necessary to treat bears in a given area as being distinct enough to become a management unit. From the point of view of representing distinct population units the CRE will probably not prove to be ideal. However, due to the history of research (Komex International 1995) and an interagency liaison group focused on the CRE (the Central Rockies Ecosystem Interagency Liaison Group), we recommend that the CRE remain as one appropriate unit for interagency coordination related to grizzly bear management.

6. PLANNING, MANAGEMENT, STRATEGIES AND PROCESSES

Goal: To continue to develop research, planning and management structures and products that will support and guide actions to achieve a non-declining grizzly bear population in the CRE.

6a. Continue to develop and detail agency specific and CRE-wide conservation strategies for grizzly bears. (P2)
The successful recovery of the Greater Yellowstone Area grizzly bear population has been achieved as a result of extensive planning, management, and legally mandated (under the Endangered Species Act) interagency coordination, all focused on the task of grizzly bear population recovery. The Interagency Grizzly Bear Committee has published their conservation strategy for grizzly bear recovery in the greater Yellowstone Area (Servheen 2003). This document is intended to guide management and monitoring of the recovered grizzly bear population. Topics include standards for the population and habitat and their monitoring, grizzly bear-human conflict management, and information and education policies. The IGBC conservation strategy is richly detailed and explicit regarding defining, monitoring and implementing recovery.

Banff National Park (2004) has published a framework for the conservation of grizzly bears. This document offers comment on strategic direction for grizzly bear management. It currently lacks the rich and important detail and specificity of the IGBC conservation strategy. We recommend it continue to evolve in that direction and that within 2 years a more detailed document be released. Complementary conservation strategies should be developed for the Alberta and British Columbia portions of the CRE. The Alberta grizzly bear recovery plan, if accepted by the provincial government, should fill this niche for Alberta (Alberta Grizzly Bear Recovery Team 2004). We have stressed the need to integrate grizzly bear conservation planning across jurisdictions.

6b. Encourage peer-reviewed publication of research regarding grizzly bear management and its scientific basis. Consider periodic program review by highly qualified scientists of the scientific basis for management. Provide opportunities for public comment and information exchange. (P2)

Because of the controversy inherent in grizzly bear management it needs to be supported by peer-reviewed, journal-published, scientific research. Peer review is a fundamental evaluation of the rigor of research or management. To further convince the public that researchers have done a good job of understanding variables influencing grizzly bear persistence and applying this to management, we recommend periodic external review by highly qualified scientists. This would be a form of broader peer review.

In British Columbia decisions related to grizzly bear hunting have generated international attention. The BC provincial government chose to have their grizzly bear population management scrutinized by a small group of population biology experts from the International Association for Bear Research and Management (the IBA), the professional association of persons involved in grizzly bear research and management. The IBA review was rigorous, published, and freely available (Peek et al. 2003). This helped to convince some people that the science was right for estimating grizzly bear population numbers to determine potential harvest rates. It did not address the issue of whether or not there should be grizzly bear hunting. This is a broader, societal issue. Scientists can predict numerical, behavioral and other biological effects of hunting, but these don’t directly address the ethical issue of hunting.

6c. Design access and facility management and planning to support grizzly bear persistence. (P2)

Maintaining the current distribution and abundance of grizzly bears in the CRE will demand bold thinking by contemporary landscape managers, for their decisions today will largely define the future of grizzly bears in the next several decades. We recommend that resource managers help society recognize that there are clear trade-offs between the level and intensity of our landuse footprint and the viability of grizzly bear populations. Recognition of these trade-offs can lead to productive discussions about acceptable thresholds for such landscape variables as road density and use, back-country visitation, and habitat area and connectivity. Clear recognition of trade-offs between social, economic, and ecological indicators, such as grizzly bear populations, is key to exploring best practice options. For example, if managers can agree that mortality along roads is a key “driver” in the grizzly bear story, then the merits of access management become a logical “what-if” scenario to explore. Not allowing the public to travel on certain roads is often controversial. However, it is a good example of the types of alternative scenarios that must be evaluated if we are to increase the likelihood of having healthy grizzly populations and the ecosystems needed to support them.
6d. Target research to address threats that have critical knowledge gaps. (P1)
Strategic targeting is a term that has been used to describe focusing research toward understanding the threats to bear populations (Servheen 1998). Grizzly bear research is expensive and yet essential to inform and support management actions. We recommend research be designed to address knowledge gaps where answers are needed for making or supporting management decisions related to threats to grizzly bears in the CRE.

7. PUBLIC, BUSINESS AND FIRST NATION INVOLVEMENT AND INFORMATION EXCHANGE
Goal: To continue to refine processes for informing and involving various societal sectors in grizzly bear management.

7a. Refine and expand societal understanding and involvement in grizzly bear management. (P2)
We define ourselves partly by our relationship with nature. Pests, beautiful, inspirational---all these are legitimate perceptions of grizzly bears. Conflict is not so much between grizzly bears and people as between different groups of people with different values. Possible resolution may evolve from recognizing the dynamic tension among people with different values and to try to ease this tension by informing, involving, and encouraging communication between concerned individuals. Respect for grizzly bears and the ecosystems that support them should be a goal. This could evolve into esteem for the bears and for nature and could contribute to a sustainable society.

Grizzly bears are a public resource. They will survive or die out in the CRE depending upon public land management policies and actions. To support grizzly bear survival people are being asked to behave in certain ways to accommodate what scientists understand to be the needs of grizzly bears and what planners think is necessary and politically possible. The scientific rationale for managing human use to support grizzly bear population persistence needs to be shared and discussed with the public. A more open, sharing and involving land use planning process could help build support for management decisions (Brunner and Clark 1997, Primm and Wilson 2004). Current research in Banff National Park is documenting different beliefs related to grizzly bear management. One aim is to find common ground (Chamberlain and Rutherford 2005). The management of this species will always be controversial (Cooper et al. 2002) because the needs of grizzly bears influence what people can do on the land in the CRE.

We recommend creation of more opportunities for the public to become informed and involved regarding grizzly bear management issues in the CRE. Management agencies have primary responsibility in this regard. To supplement their efforts in the CRE we recommend widespread dissemination of the ESGBP final report results and regular public contact by the ESGBP Implementation Committee (please see recommendation 9). Grizzly bear conservation will be strongest when it is both top down (strong government support) and bottom up (strong involvement of grassroots interests) (Primm and Wilson 2004).

7b. Establish a mechanism to maintain some of the public involvement and information that were part of the Eastern Slopes Grizzly Bear Project. (P2)
The ESGBP Steering Committee met about 3 times a year for 9 years. Attendees were representatives of major donors from business and industry, researchers, government, conservation groups and other stakeholder groups. Meetings usually had a cooperative and open spirit with a frank exchange of information and ideas. Through public presentations and our website, www.canadianrockies.net/Grizzly, and the newsletters of Steering Committee member organizations, we shared findings with supporters and the public. Some tangible evidence of communication success, at least within the Steering Committee, can be implied from the project’s having been funded by the Steering Committee and other sources for 11 years. Communication with interested parties was a fundamental part of the ESGBP. This communication should continue through the project’s implementation phase and be spearheaded by the Implementation Committee (please see recommendation 9).
7c. Develop further communication with First Nations regarding grizzly bear mortalities, ecology and management.  (P1)
Significant numbers of grizzly bear mortalities occurred on First Nation lands. Some were unintentional and related to food or garbage attractants (Chapters 6.2 and 6.4, this report). The ESGBP was unsuccessful in attempts to discuss grizzly bear issues with First Nations. We recommend that this is important communication that needs to be done.

8. FUNDING TO MAINTAIN GRIZZLY BEARS
Goal: To adequately fund research that will inform and support maintaining a non-declining grizzly bear population in the CRE.

8a. Adequately fund research, management and planning directed toward long-term maintenance of grizzly bear populations. Use multi-stakeholder funding approaches developed by the ESGBP to do this. (P1)
Development and use of the CRE will continue. To plan for and manage the effects of development on grizzly bears will require research, understanding, and monitoring that is integrated into management and planning. Grizzly bear-human conflict prevention and management require funding to be successful. One of the strengths of the ESGBP has been its ability to raise funds from diverse sources including business and industry, foundations, government, academia, and conservation groups (Herrero et al. 1998). This has allowed research to be carried out over multiple years and across jurisdictional boundaries. This regionally integrated and multi-stakeholder approach to funding grizzly bear research and monitoring is a model that should be continued. Such a multi-stakeholder funding proposal could be developed by the Central Rockies Ecosystem Intergency Liaison Group (CREILG), or it might come from a business, conservation or university group.

9. IMPLEMENTATION OF ESGBP MANAGEMENT RECOMMENDATIONS
Goal: To achieve the goals and to implement the management recommendations of the ESGBP

9a. Form an ESGBP implementation committee. (P1)
This group would have representatives for the diverse interests of members of the ESGBP Steering Committee. Initiative to form it would probably have to come from outside of government. Once formed it should create an implementation strategy and structure. Such an approach would take advantage of the 11 years of effort that have gone into the ESGBP, its results, its public profile, and the need for action to conserve grizzly bears in the CRE. Communication with a wide audience would also be an important task for this committee. This group would work closely with Alberta’s Grizzly Bear Recovery Team. One model for this group could be the Prairie Conservation Action Plan Implementation Committee lead by Ian Dyson of Alberta Sustainable Resource Development in Lethbridge. In the approximately 16 years since completion of the first Prairie Conservation Action Plan (World Wildlife Fund Canada 1988), regular, yearly progress has been made toward its implementation.

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15. Eastern Slopes Grizzly Bear Project's management recommendations — S. Herrero

FINAL REPORT OF THE EASTERN SLOPES GRIZZLY BEAR PROJECT – 2005


PUBLICATIONS RELATED TO EASTERN SLOPES GRIZZLY BEAR PROJECT DATA


———, P. Miller, and U. Seal (editors) 2000. Population and habitat viability assessment for the grizzly bear (Ursus arctos) of the Central Rockies Ecosystem. Eastern Slopes Grizzly Bear Project, University of Calgary, Calgary, Alberta, Canada, and Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, Minnesota, USA.


PROJECT WEBSITE

www.canadianrockies.net/Grizzly Most of the ESGBP publications plus considerable other related material can be found here and are available for downloading.
AFTERWORD

Stephen Herrero

It is easy to convince people who value nature that it is worthwhile to maintain grizzly bears and the ecosystems that support them. For people who seek to understand and who may love nature, the evolution of living systems can become a grand pageant of life. Grizzly bears are one of this drama’s stars. They are stars because they are the largest land Carnivores left in the world. People readily recognize the awesomeness of such an animal. Such mega fauna take millions of years to evolve but can be lost in decades. Human beings had a major role in the extinction of large mammalian species in North America such as mammoths and mastodons. These species flourished until Clovis hunters began expand their populations about 13,000 years ago. Today in the Central Rockies Ecosystem and elsewhere grizzly bears will die out or survive because humans decide that these bears are, or are not, valuable. But valuing grizzly bears is not sufficient for their conservation. In addition we must be willing to plan and execute our activities in grizzly bear habitat to meet their needs and only those needs of humans that do not cause grizzly bear population decline. This is a big order for a development-oriented society like ours.

Because of their size, power and the ability to kill or injure other animals, as well as their focused and gentle care for cubs, people are fascinated by grizzly bears. People knowing they may encounter such an animal naturally seek out information about the bear’s behavior and ecology. At the least, grizzlies and people who seek to conserve them, have a broad audience. But how does interest become translated into conservation action when most people live in cities and don’t have a direct, day by day, interest in what goes on in grizzly bear habitat? Large animals like grizzly bears require productive land to survive. Human beings are attracted to such land for development and recreation. The temptation is to take from land whatever we can make money on. In the Central Rockies Ecosystem activities such as oil and gas development, forestry, recreation and resort development represent obvious economic opportunities. In the pursuit of these opportunities the needs of grizzly bears are usually not primary.

As a society we are at a crossroads for managing the effects of people’s activities and developments on sensitive species such as grizzly bears. The Eastern Slopes Grizzly Bear Research Project and other research present a scientific assessment of the status and needs of grizzly bears in our region. We must understand and meet these needs if the bears are to survive. As I see it, where we are able to maintain sensitive species like grizzly bears and woodland caribou, we are living sustainably, within our means. To me species are our kin and keys to understanding the pageant of life on earth and the potential we have to live with and learn from this pageant.

I find hope for grizzly bear conservation and for living more sustainably without dismembering nature. This hope comes from the energy and commitment of the researchers and assistants who were part of our project. The primary researchers, the graduate students, gave major portions of their lives to doing a good job. Long, long hours, physical hardship, danger—these things may sound exciting when one reads about them but staying in the field while they are happening requires toughness and dedication. But today’s grizzly bear researcher is not only tough; they also must be smart, for the interface from the field to the computer happens often and with as many demands on the brain as on the body.

I also find hope from the financial supporters of the ESGBP. The ESGBP was planned to be a 6 year project with 5 years of field data and 1 year for write up. After 5 years we found out that because of the low reproductive output of the grizzly bears we were studying, we would need at least 8 years of data to have acceptable confidence in birth, death and population growth rates. Supporters dug deep into their budgets and in the end 9 years of field data and 2 years of write up were supported. I think this is a strong vote for the importance of research on grizzly bears in the Central Rockies Ecosystem. It also indicates that our many and diverse financial supporters continued to believe in the desirability of basing grizzly bear conservation on scientific research.
The enormous economic juggernaut of our society is very rapidly transforming planet earth. The biological fabric that evolved over billions of years is now going through human-caused transformations and extinctions. If we maintain grizzly bears in the CRE without decline then we will have taken our step toward sustainable and inspired living.
APPENDICES


<table>
<thead>
<tr>
<th>Year</th>
<th>Unduplicated females with COY</th>
<th>Human-caused mortality</th>
<th>Human-caused mortality 6-year running averages</th>
<th>Minimum population estimate</th>
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*Beginning in 2000, probable human-caused mortalities are used in calculation of annual mortality thresholds.*
DESCRIPTIONS OF AND CREDITS FOR ILLUSTRATIONS AT THE BEGINNING OF EACH CHAPTER

Stephen Herrero

The map of the ESGBP study area and surround was created by Scott Jevons of Alberta Community Development and enhanced by Karin Herrero of KH Communications. This map appears on each Chapter’s frontispiece. It is accompanied by photographs and our logo (see lower right of page) which was created by Rob Storeshaw of Parks Canada. Our sincere thanks to all who contributed images, and apologies to the “unknown” photographers.

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<td>Jack Butler (right in photo), then forest ranger at the Bighorn Ranger Station and John Wambke, with large, home-made bear trap used by ranchers to trap problem grizzlies in the Sheep River, Alberta (photo, about 1947).</td>
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