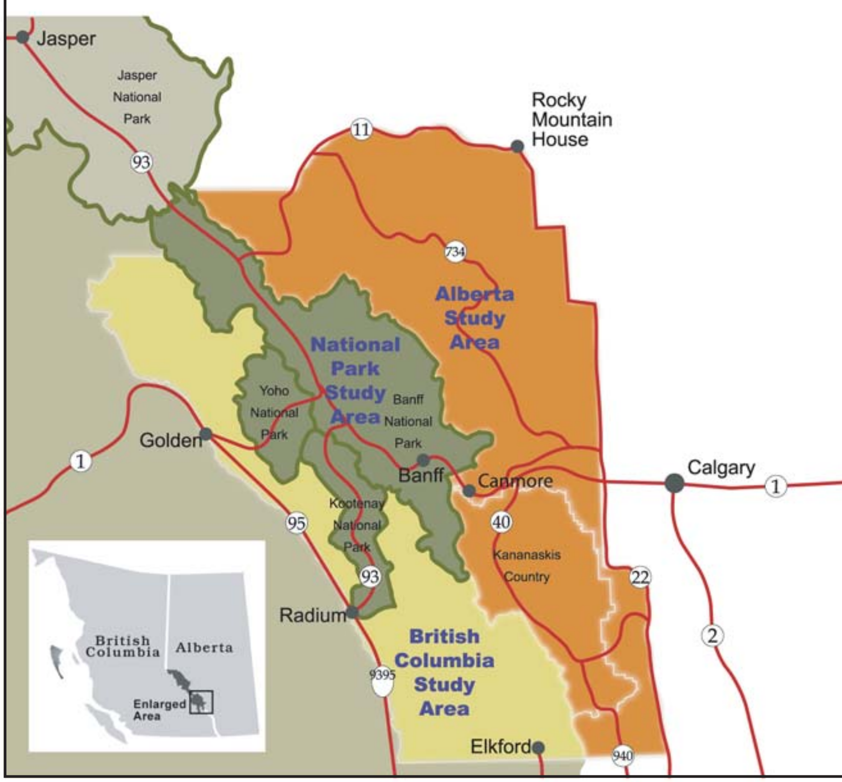
CHAPTER 7

EAST SLOPES GRIZZLY BEAR FRAGMENTATION BASED ON GENETIC ANALYSES



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7. EAST SLOPES GRIZZLY BEAR FRAGMENTATION BASED ON GENETIC ANALYSES

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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; F_{ST}, 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_{ST}. 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.

Pop Pairs	FST	Separation
ESN-NRW	0.012	CD
ESN-ESS	0.013	Highway 1
ESN-FMF	0.027	Distance
ESS-CRS	0.028	CD
CRS-SRS	0.035	Highway 3

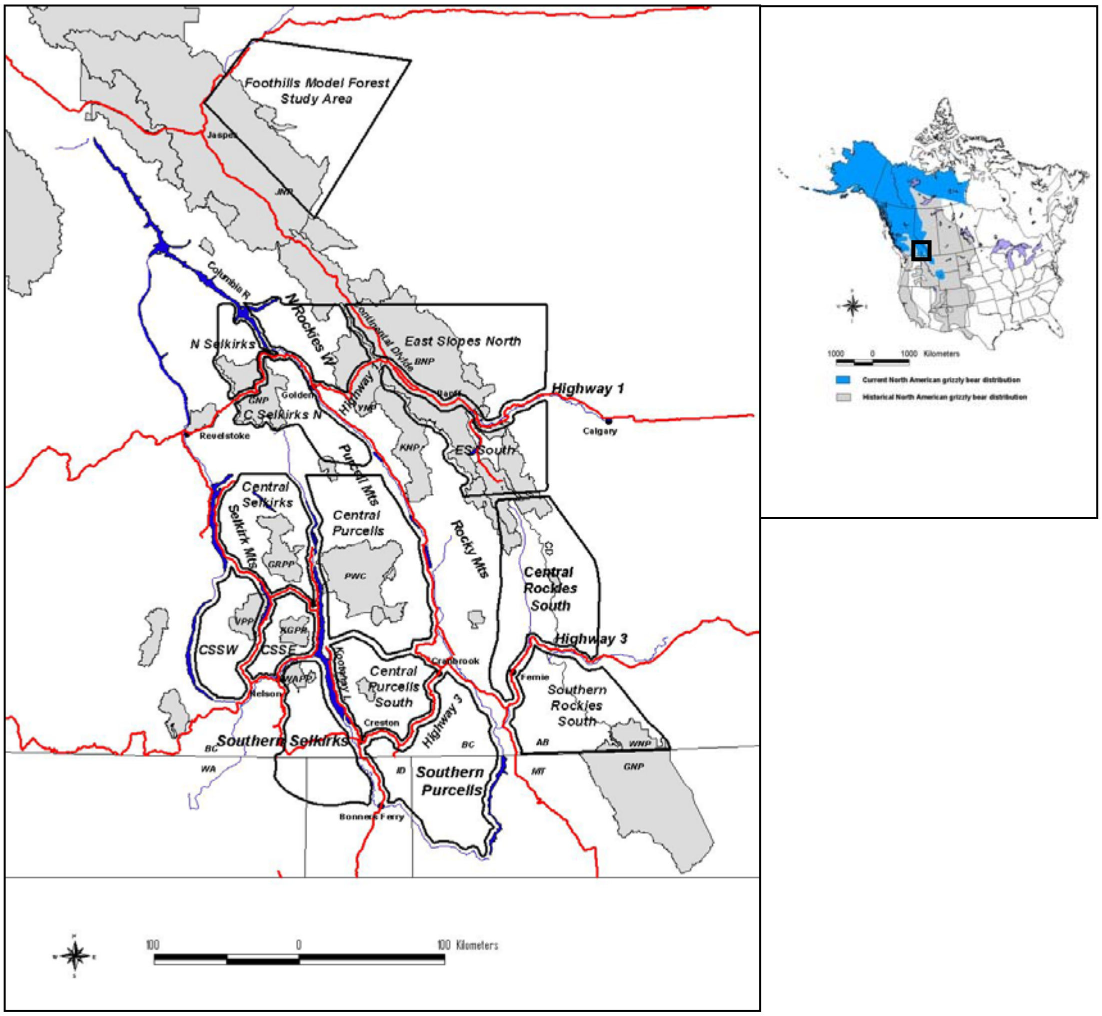

Figure 1. East Slopes study area in regional context of larger genetic-based movement and fragmentation study. East Slopes North and East Slopes South (ES South) areas are the primary focus of this report. Other outlined areas were also genetically sampled and boundaries are arbitrarily set for analysis 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 (KGPP), 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 similarly large populations north and south of Highway 3 in the Rocky Mountains to the south where the genetic differentiation is approximately 3 times greater ($F_{ST} = 0.035$) 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.

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