Transborder Purcell and Selkirk Mt. Grizzly Bear Project

Annual Report 2007
The Canadian Edition

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Executive summary

This report is the first annual report for the Transborder Purcell Selkirk Grizzly Bear project, the Canadian Edition. Our work is centered on the transborder Purell/Yaak and south Selkirk grizzly bear populations. The goal of this project is to use research and management to mediate recovery efforts for both of these small fragmented grizzly bear populations. Both trans-border populations are small, fragmented, and legally threatened in Canada and the US and at the southern edge of a contracting distribution. We are an international cooperative research team that has been working as such since 2003. The threats to these population include excessive human-caused mortality, population fragmentation, and inadequate habitat security. Here we report the cumulative work we have accomplished within Canada since 2004 (with a few results that include work by M. Proctor that began in 1998, in the Canadian Purcell Mts). The US Fish & Wildlife Service has been working on recovering these populations from within the US for 15 years. This report covers four components of our international recovery work: human-caused mortality reduction, improving inter-population connectivity, improving habitat security, and education and integration of government, industry, and the public.

In the realm of mortality reduction, we have done a spatially explicit mortality analysis that summarizes the patterns of increasing human-caused mortality in the ecosystems over the past 25 years. This report became the impetus to hire a grizzly bear “Bear Aware” specialist in conjunction with the BC Bear Aware Program. We have provided research-derived data to regional BC Provincial biologists and managers that has allowed improvements in management strategies that have been instrumental in creating a no hunt buffer to allow for linkage and population recovery and provided research-derived population estimates for the Grizzly Bear Population Units (GBPU) that allows for accurate hunt quotas in GBMUS immediately adjacent to the threatened GBPUs.

In the realm of improving inter-population connectivity, our research has identified several important “linkage zones” across BC Hwy 3 in the Purcell Mts. We have carried out 2 years of DNA survey work and used the results to predict high quality linkage habitat. We have put GPS radio collars on grizzly bears near BC Hwy 3 for 3 years in an effort to find out where remnant connectivity still exists. Our results have identified several “linkage zones” where we are focusing efforts to provide habitat security and enhance inter-population movement. This effort includes purchasing strategic linkage habitat where necessary, working with the timber industry and government to manage linkage habitat appropriately, and to reduce bear attractants and thus mortality in linkage zones.

In our efforts to improve habitat security, we used our DNA survey data and GPS radio telemetry data to develop seasonal habitat quality maps that will underpin a community wide, discussion of creating habitat security for grizzly bears through access management. This effort entailed an analysis of current habitat conditions (available core habitat and road densities) that is being integrated with grizzly bear habitat needs and human access needs (the timber industry, hunters and recreationists).

W also report our ongoing efforts to educate and integrate government, industry, and the public. We meet regularly with local and regional BC Provincial biologists and managers, sharing our results and discussing relevant management options. Often our results are incorporated into management actions in a timely manner. We work with Tembec, the major timber company in the south Purcell Mts. in their efforts to become "certified" and have delineated high quality grizzly bear habitat for them and provided management guidelines on their activities within these areas. We have instigated discussions with the hunting and recreation communities, sharing our results and initiating their support for necessary management activities for grizzly bear recovery. We also give regular talks in all the communities within and adjacent to these populations.

Introduction

Recent research has found that the trans-border south Selkirk and south Purcell/Yahk grizzly bear populations are a conservation concern (Fig. 1). The south Purcell/Yahk population is small (< 50 bears), fragmented (limited inter-population movement with its immediate neighbours Proctor et al. 2005a) and is declining at ~3.7% annually (Wakkinen and Kasworm 2004). The south Selkirk population is also small (< 100 bears), genetically and demographically isolated from its immediately adjacent neighbor (less than 2-5 km away) (Proctor et al. 2005a), and considered stable or slightly increasing (Wakkinen and Kasworm 2004). The fragmentation is a result of human-caused mortality, human settlement, and highway traffic (Proctor 2003, Proctor et al. 2005a). The BC Ministry of Environment Ecosystems Branch considers both populations threatened and estimates that there are less than half the number of bears than the habitat could support (Hamilton et al. 2004). In the USA both populations are also threatened (US Endangered Species Act, USFWS 1993). These populations are at the southern edge of a contracted distribution and represent the front lines in resisting any further range contraction in the region (McLellan 1998). Clearly, their long-term persistence will require reduced human-caused mortality, adequate habitat security, and being functionally connected to neighboring areas and this situation has a regional, provincial, and international significance. BC is committed to maintaining its current distribution of grizzly bears and has international commitments to cooperate in cross-border endangered species management.

In response to this conservation status, we initiated an international cooperative research effort to use scientific research to understand conservation issues surrounding these populations then develop and implement internationally integrated workable management strategies to return these populations to self-sustaining status. Our immediate team consists of the US Fish & Wildlife (USFWS) Grizzly Bear Recovery team (Dr. Chris Servheen, US Grizzly Bear Recovery Coordinator, Wayne, Kasworm, Cabintet/Yaak Recovery Biologist, and Tom Radandt trapping biologist) and Dr. M. Proctor from British Columbia, Canada. The USFWS has been working to recovery these populations from within the US for the past 15 years (Kasworm et al. 2006). While they have made great progress, we realized that half of their populations, problems, and solutions lie within Canada. Our extended team consists of many other government agencies, biologists, managers, and ENGOs (see Acknowledgements).

As part of a comprehensive strategy we are concentrating on 4 necessary management issues. 1) reducing human-caused mortality, 2) improving inter-population connectivity, 3) improving habitat security and managing motorized access and 4) educating and integrating the public and industry. These management issues are interrelated and must be dealt with in a comprehensive integrated strategy. We strive to integrate government agencies responsible for managing these populations, initiate the cooperation and involvement of local industry operating on the land, integrate ENGOs that have interest and resources for implementing solutions, and include the public through education and direct involvement where appropriate.

This first annual report details the progress we have made over the past 3 years. Its structure mirrors our overall approach. In each of our four focal areas we outline the research defining the problem, the research suggesting the solution, the development and implementation of management plans.

Figure 1.a) Current and historic distribution of grizzly bears in North America. b) western North American scale grizzly bear distribution, c) Rocky MT peninsular grizzly bear distribution, d) threatened trans-border populations. Blue estimates current grizzly bear distribution, green represents protected areas, red lines are major highways.

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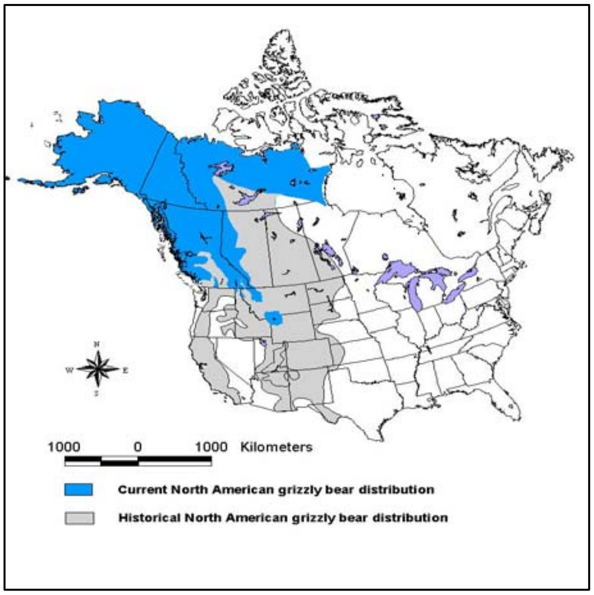

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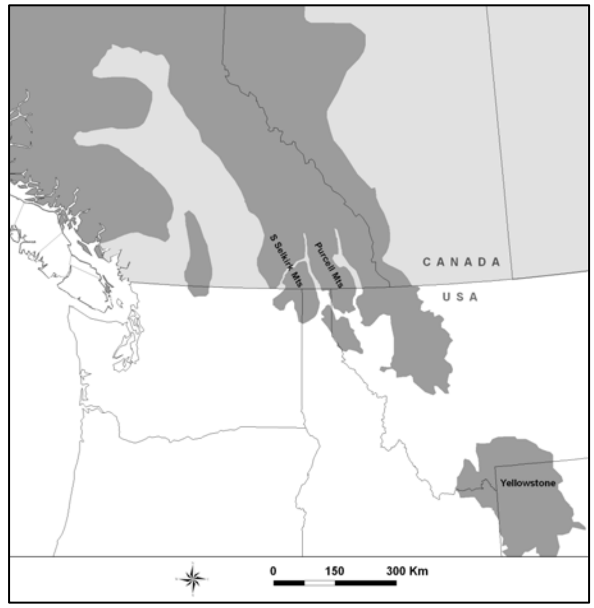

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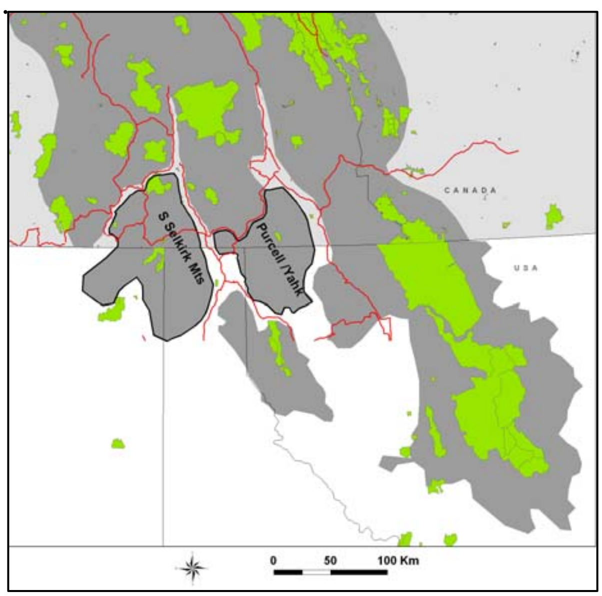

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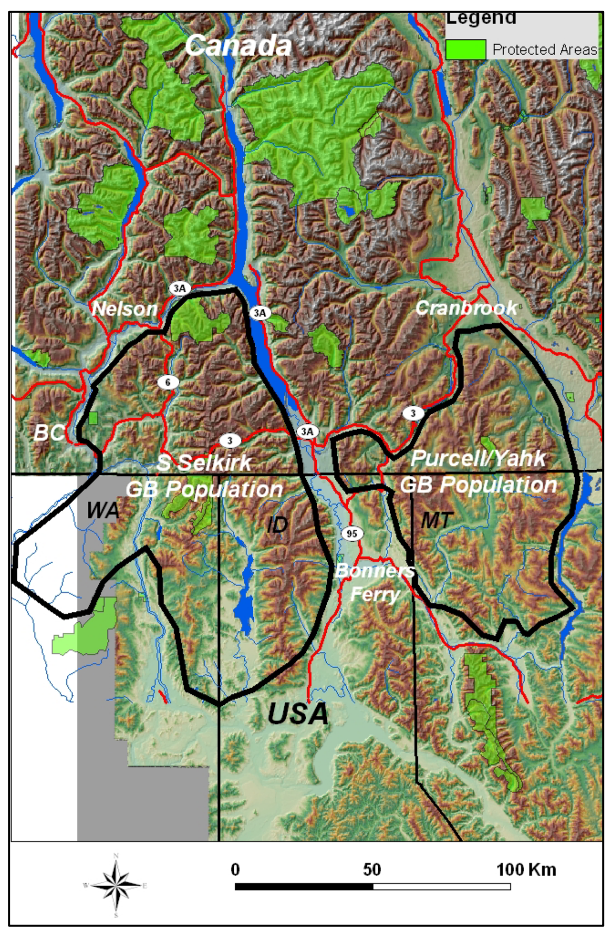


Chapter 1 - Reduction of human-caused mortality

Human-caused mortality is often the dominant factor driving grizzly bear population dynamics (McLellan et al. 1999). Many researchers have shown that the most important population metric for understanding grizzly bear population dynamics is adult female mortality (Knight and Eberhardt 1985; McLellan 1989a; Hovey and McLellan 1996; Mace and Waller 1998; Garshelis et al. 2004) and the reproductive rate. This information supports the argument that tracking causes of female mortality is of paramount importance and is required to develop appropriate responsive management. For instance, in the Yellowstone ecosystem, Knight and Eberhardt (1985) found that adult female survival was the most important cohort and reproductive parameter influencing population trend. After determining the specific causes of mortality, managing human-caused mortality became the centerpiece for effective management that has been applied for the past 10-20 years (USFWS 1993; Servheen et al. 2004). Today, recovery of the population has progressed to the stage where the Yellowstone grizzly bears are being de-listed under the US endangered Species Act (C. Servheen pers. comm.).

We carried out a spatially explicit human-caused mortality analysis of grizzly bears for the south Purcell/Yahk and south Selkirk ecosystems. This analysis is a stand alone report and here we provide a brief summary in the form of the Abstract from that report (Proctor et al. 2005b)

Mortality analysis report Abstract

Canadian and US trans-border grizzly bears in the south Selkirk and Purcell-Yaak ecosystems live in small fragmented threatened populations. Reducing human-caused mortality where feasible is an important strategy for “recovery” of these populations. We examined patterns of human-caused mortality spatially and temporally in these ecosystems by reviewing 29 years of mortality records from the US Fish and Wildlife Service, Idaho Fish and Game, and the British Columbia Ministry of Environment (Table 1). This report crystallizes three important points:

1) human-caused mortality rates in these ecosystems are likely contributing to declines in the Purcell-Yaak area and may be limiting growth in the Selkirk Mountains
2) the vast majority of Canadian grizzly bears are being killed after being attracted to residences and small farms on the periphery of these ecosystems
3) actions focused on reducing bear attractants in settled areas may improve several bear management issues:

- reducing human-bear conflicts,
- reducing bear mortality and thus improving survival rates in and around these threatened populations, and
- reducing attractants, allowing inter-population linkage without increasing human-bear conflicts in linkage zones.

We found human-caused mortalities to be increasing in both ecosystems (Fig. 1 & 2), culminating in a known mortality rate averaged over the past 6 years of an estimated 4.0% of the Purcell-Yaak population and 3.0% of the south Selkirk population. Males were killed more often than females, sub-adults (1-5 yrs. old) more often than adults, and deaths were more likely to occur in the fall than the spring and summer combined (Table 1). In the recent decade, we found that 75% of Canadian non-hunting mortalities occurred as a result of attractants at residences and small farms from fruit trees, livestock and feed, and garbage (including 3 self-defense kills at residences and several unspecified causes at attractant sites) on the periphery of these ecosystems (Table 2, Fig.2). The other category was backcountry mortalities in the eastern portion of the Purcell-Yaak area which included mistaken identification, illegal kills, self-defense, black bear hound hunters, and several of unknown cause resulting in 11% of known mortalities (Table 2). We make recommendations for strategies to reduce these mortalities within Canada, as the US has on-going organized efforts aimed at minimizing grizzly bear mortalities. We recommend using the existing well organized BC Bear Aware program modified to encompass the rural scattered nature of on-site attractant-based grizzly bear mortalities occurring on the periphery of these ecosystems. We also recommend a committee of relevant interested community and government individuals be formed to guide these efforts. We further recommend that a member of this research team and a local conservation officer approach the local hunting community using the east Purcell-Yaak area for discussions on the solutions to the backcountry mortality occurring in that region. And finally, we recommend that hunting be eliminated south of Highway 3 in the Purcell Mountains (South Purcell Grizzly Bear Population Unit) and a no hunting buffer around these threatened populations be considered to facilitate population interchange.

Table 1. Summary of human-caused grizzly bear mortalities in the south Selkirk and south Purcell / Yaak ecosystems from 1976 through 2004. Mortalities span both the US and Canada and include a 15 km perimeter.

CATEGORY			Purcell/Yaak	S Selkirks	Both % ot total	Total
Total human-caused mortalities			110	84		194
Human-caused morts, no hunting			52	47		99
		male	28	25	**0.54**	**53**
		female	21	14	0.35	**35**
		unknown	3	8	0.08	11
	Hunting	**US**	0	0		
		Canada	51	30	0.45	81
	Age	**<1**	4	6	0.15	10
		1-5	18	16	**0.52**	**34**
		>5	11	11	0.33	**22**
	Season	**Spring**	11	9	0.20	20
		Summer	3	7	0.10	10
		Fall	38	31	0.70	69
	Private land	**US**	5	1	0.06	6
		Canada	25	21	**0.46**	46
	Public land	**US**	11	13	0.24	24
		Canada	11	12	0.23	23
Within 500m of road						
	US	**yes**	13	7	0.20	20
		no	3	5	0.08	8
		unk	0	2	0.02	2
	Canada	**yes**	29	27	0.57	56
		no	7	3	0.10	10
		unk	0	3	0.03	3
GENERAL CAUSES						
		Mistaken ID	7	3	0.10	10
		Poaching/ Illegal	2	7	0.09	9
		Unknown	0	2	0.02	2
		Under Investigation	6	3	0.09	9
		Self-defense	13	4	0.17	17
		Train	2	0	0.02	2
		Research	1	0	0.01	1
MANAGEMENT MORTALITIES						
		Fruit trees	0	7	0.07	7
		Livestock	7	5	0.12	12
		Garbage	3	1	0.04	4
		Property	1	1	0.02	2
		Unknown	9	17	0.26	26
TOTAL			**51**	**50**		**101**
Known deaths / year*			1.76	1.72		
Known deaths / yr last 6 years*			3.5	2.8		
Known deaths / yr last 6 years**			2.2	3.0		
	Percent of population**		4.3%	3.0%		

*** includes bears in ecosystem & periphery**
**** includes only bears within ecosystem**

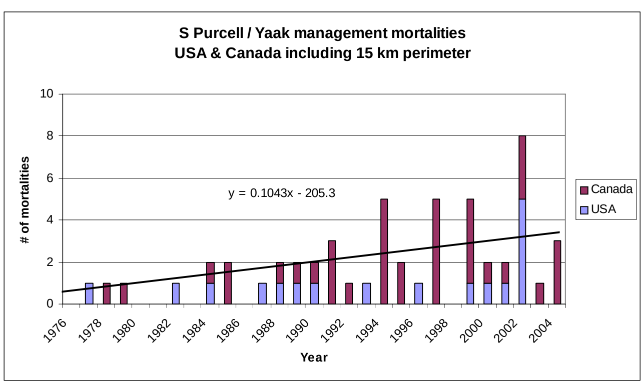
Table 2. Summary of human-caused mortality (non-hunting) in the south Purcell-Yaak and south Selkirk ecosystems in the most recent decade from 1995-2004. The Can : US column refers to the number of mortalities in each category that occurred in Canada or the US.

Recent Decade 1995-2004	Purcell/Yaak	S Selkirk	Total	Can : US	Proportion of total
Human, unknown*	7	5	12	10 : 2	0.22
Under investigation	6	3	9	0 : 9	0.16
Livestock	4	4	8	7 : 1	0.15
Self defense**	6	2	8	7 : 1	0.15
Fruit trees	0	7	7	7 : 0	0.13
Mistaken ID	2	2	4	2 : 2	0.07
Garbage	2	1	3	3 : 0	0.05
Property damage	1	1	2	1 : 1	0.04
Train	2	0	2	2: 0	0.04
TOTAL			55		

*All 10 of the Canadian unknown mortalities resulted from being attracted to a residence or farm
**Includes some BB hound hunters

Figure 2. Human-caused grizzly bear mortalities in the a.) south Selkirk and b.) south Purcell / Yaak ecosystems from 1976 through 2004. Mortalities span both the US and Canada and include a 15 km perimeter. Hunting and natural mortalities are not included.

a,



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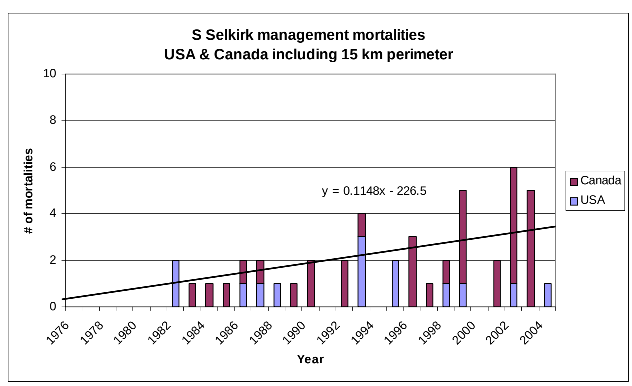

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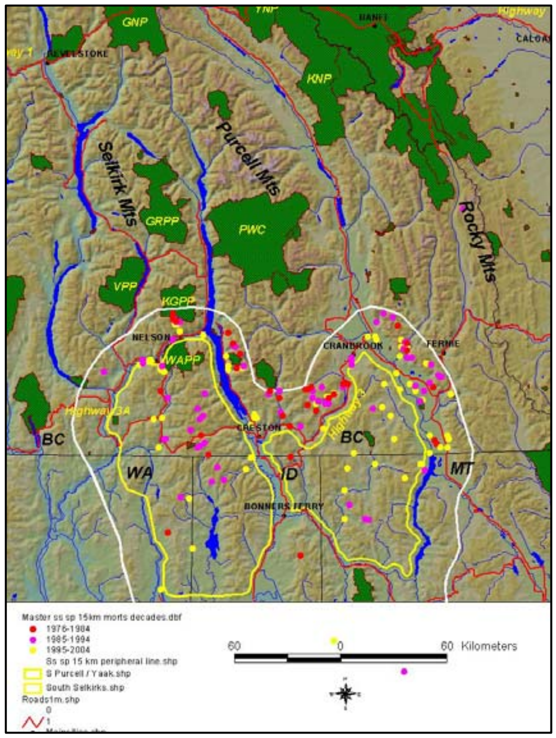
Figure 3. Map of human-caused grizzly bear mortalities in the south Selkirk (orange polygon) and south Purcell / Yaak (yellow polygon) ecosystems by decade. Mortalities span both the US and Canada and include a 15 km perimeter (white line). Included are: human-caused mortality between 1976-1984 (red dots), 1985-1994 (pink dots), 1995-2004 (yellow dots). Green shaded areas are protected; PWC is the Purcell Wilderness Conservancy, GRPP, KGPP, VPP, and WAPP are Goat Range, Kokanee Glacier, Valhalla, and West Arm Provincial Park respectively.



Mortality – population estimation

Another aspect of mortality management is to asses the population sizes for the 2 threatened populations as well as the adjacent populations that are being legally hunted. In 2004 no reliable population esitmates existed the south Selkirk and south Purcell/Yaak populations. The value of these estimates is they verify the conservation status, provide a benchmark to track the recovery progress, and allow for an accurate assessment of mortality rates (number of mortlaities relative to population size. Accurate population estimates in the immediately adjacent populations also allow for a conservatoin assessment, accurate assessment of mortality rates, and accuate setting of hunt quotas.

British Columbia manages grizzly bears by Grizzly Bear Populaiton Units (GBPUs). The Canadian portions of the Purcell/Yahk and South Selkirk transborder populations are roughly contained within the Yahk and South Selkirk GPBUs (Fig. 4). BC considers both of these populations threatened and therefore do not allow a legal hunt while the adjacent GBPUs, S Purcell, Central Purcell and Central Selkirk GBPU are considered healthy and are legally hunted.

This past year (2006-2007) we analyzed the cumulative results of 6 different DNA surveys that have been carried out by our reaserch team in 2004 and 2005 and by M. Proctor during the past decade. With the help of John Boulanger we estimated the population sizes of the S Selkirk, Yahk, S Purcell, C Purcell GBPUs. This effort is also documented in a stand alone report (Proctor et al. 2007a; Appendix II to this report) that was submitted to the BC Ministery of Environment. The estimates containted in this report have been accepted by Provincial biologists and managers and are being used as their official estimates. The Province has adjusted hunt quotas in the south and central Purcell GBPUs accordingly. Note that these new estimates that were based on DNA survey work designed for population estimation, were considerably lower than traditional Provincial estimates (~50%) and this represents a significant improvement in grizzly bear management in this region. Besides resetting hunt quotas, the Province also lowered the quota rate, effectively managing to allow populaton increases within the huntable South and Central Purcell GBPUs. The third notable change to grizzly bear management is that the Province has initiated a no hunt buffer around the Yahk GBPU. The regional data was presented to local hunter and outfitters and they voluntarily agreed to accept these needed management changes (G. Mowat pers.comm.)

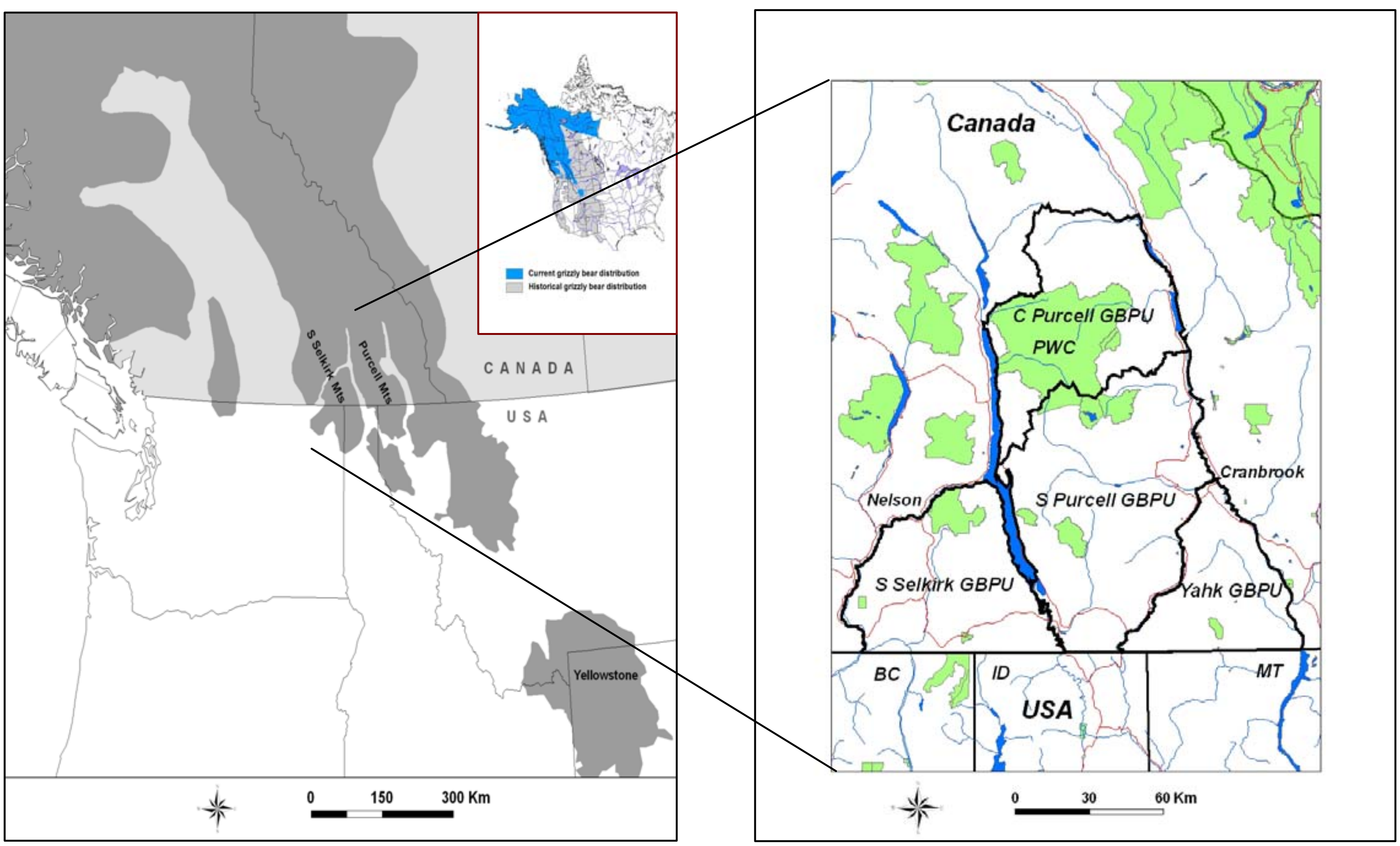
Here we briefly summarize the methods, results of the full report.

Summary of Purcell / Selkirk population estimation report

Population estimates can be crucial for setting hunting quotas, particularly for species with low reproductive rates. Grizzly bears exhibit low productivity (Bunnell and Tait 1981) and are susceptible to human-caused mortality other than legal hunting (McLellan et al. 1999; Nielsen et al. 2004a). British Columbia has a legal grizzly bear hunt throughout most of its occupied range and BC Provincial biologists and managers are faced with the challenge of obtaining accurate population estimates to better manage the legal hunt across what is a vast province with varied ecosystems. Due to inherent challenges in sampling grizzly bear populations, estimation of population size has frequently relied on extrapolations of benchmark populations and managerial expertise, and that rely on habitat or other variables which are not directly affected by changes in grizzly bear abundance Ten years ago DNA sampling of wild bears was first suggested and demonstrated as a method for rapid (within 1-year) estimation of population size (Woods et al. 1999; Mowat and Strobeck 2000). Since that time over 26 grizzly bear DNA surveys have been carried out in BC and Alberta (Proctor et al. 2007b). Undoubtedly, this method has revolutionized population estimation of bears within Canada, North American, and across the world. Recent surveys have applied improvements in methodology and design that have brought significant improvements in precision and bias (Boulanger et al. 2004, 2005, 2006; Proctor et al. 2007b). Methods also have been developed that allow for ecological-based extrapolation of grid estimates. Resource selection function (RSF) models have been used for predicting grizzly bear occurrence and habitat use for many purposes (Mace et al. 1996; Mace et al. 1999, Boyce and Waller 2000; Nielsen et al. 2002; 2004a; 2004b; 2006). We have integrated a variation of RSF modeling to extrapolate population estimates beyond sampling grids to ecosystem boundaries, thus providing biologically realistic estimates of population size by adjusting for habitat condition (Boyce et al. 1999; Apps et al. 2004). Here we report a meta-analysis of 6 such DNA surveys carried out over 5 years in adjacent ecosystems of the central and southern Purcell and Selkirk mountains of southeast BC which represent the Yahk, South Purcell, Central Purcell, and south Selkirk GBPUs (Fig. 4).

Figure 4 a) Current western North American grizzly bear distribution and b) Grizzly Bear Population Units (GBPUs) within the south Selkirk and Purcell mountains.

a) b).



Methods - Population estimation

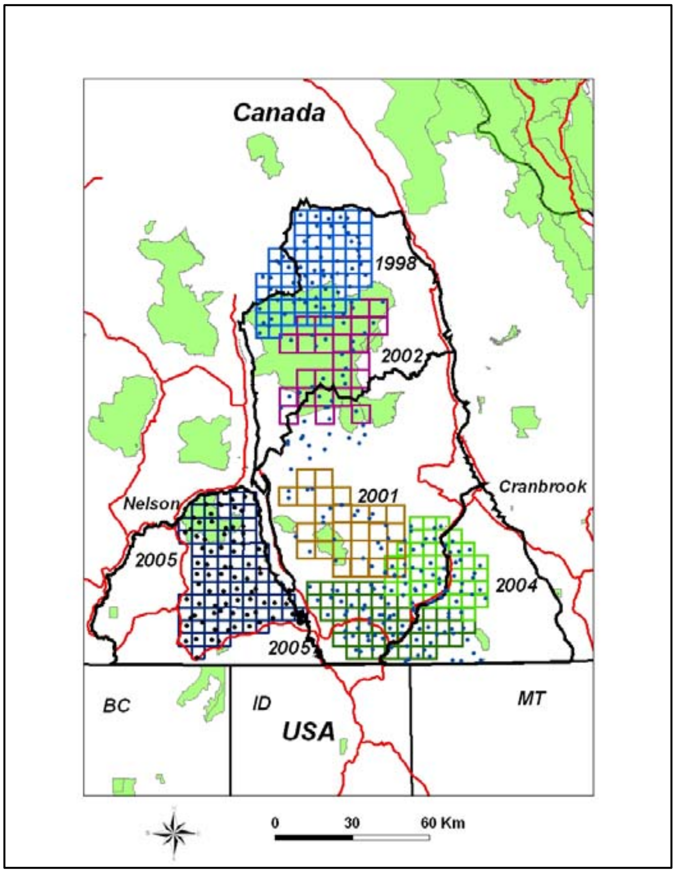
We used DNA hair snag methods and mark-recapture study design to estimate population size in 6 grids (Table 3) over a 5 year period for 4 adjacent GBPUs (Fig.5a). We used a meta-analysis within the software program MARK (White and Burnham 1999) to improve precision of individual grid estimates (Boulanger et al. 2002). Field methods were standardized within each grid and followed protocols detailed in Woods et al. (1999) which entailed use of rotted blood and fish scent lure at barb wire hair-snag stations to collect bear hair for eventual DNA "fingerprinting" analysis. Genetic identification of individual bears (carried out at Wildlife Genetics International, Nelson BC) allows capture histories to generate mark-recapture data from repeated sample collections. Genetic errors were minimized according to Wood et al. (1999) and Paetkau (2003). All surveys used 4, 2-week hair collection sessions and sites were not moved between sessions. Four grids used 5km x 5km ($25km^2$) cells (1 site / cell) and 1 grid used a sampling intensity equivalent to a 7km x 7km ($49\ km^2$) grid while another used a sampling intensity equivalent to a 8 km x 8km grid (Table 3). In the two grids with lower sampling intensities, site selection varied slightly from the strict grid design. We therefore drew convex polygons around the composite sampling area and computed the average area sampled by 1 DNA site. Grid estimates were combined, corrected for closure violation using radio telemetry (Boulanger et al. 2004) or core extrapolations (Boulanger and McLellan 2001) and extrapolated based on habitat modeling (Apps et al. 2004) to entire GBPUs (Fig. 4). Extrapolation relied on ecological probability of occurrence modeling (Manley et al. 2002; Apps et al. 2004) the details of which are presented in Chapter 2 – Linkage Enhancement)

Table 3. Study area grids used for DNA surveys of grizzly bears in Purcell and S Selkirk mountains of southeast BC with meta-analyses derived population estimates. $\hat{p}$ is the capture probability which represents an estimate of the number of bears captured within each session relative to the total population

Study area	Year	Area	GBs	N (95% CI)	$\hat{p}$
Jumbo	1998	1650	28	37 (32-45)	0.27
S Purcells	2001	1500	29	41 (35-55)	0.34
Purcell Wilderness Conservancy	2002	1300	36	50 (43-66)	0.42
Hwy 3 east	2004	1125	12	16 (14-21)	0.27
Hwy 3 west	2005	1375	20	23 (20-30)	0.33
S Selkirk	2005	1950	30	36 (32-45)	0.49
Total		8900			

Figure 5. a) DNA grids & sites within the Purcell and Selkirk Mountains of BC b) DNA captures DNA sites outside of grids were not used for population estimation but were used for model extrapolation. Green areas are protected, red lines are highways.

a)



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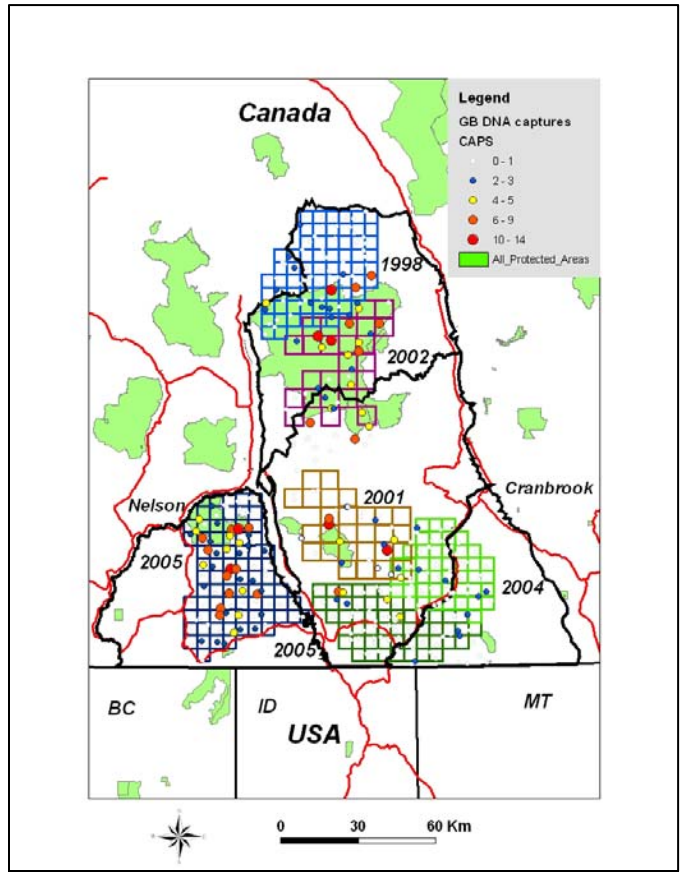


Results – Population estimation

The 6 grids we used in our meta-analysis covered 8900 km^2 where we sampled 293 DNA hair-grab sites (Table 3, Fig. 5a). We detected 148 different grizzly bears in 264 capture events (Table 3, Fig 5b). The capture probabilities for the grid estimates range from 0.27 to 0.49 and average 0.35 (Table 3). The closure correction for the southern portion of the Purcell Mts grids was based on the proportion of GPS radio locations occurring within the grid was found to be 0.73 (SE=0.11, n=9 bears). In the northern portion of the Purcell Mt. grids the closure correction was found to be 0.87 (SE=0.19, n=2 N estimates) (see Boulanger, Appendix I within Strom et al. 1999).

Extrapolation modeling for both the north and south study areas yielded probability of occurrence models that were averaged over 3 scales (Fig 6).

In our ecological habitat modeling used to extrapolate the grid estimate to entire GBPUs we found that habitat associated with grizzly bear detections in our DNA surveys was very consistent across study areas. Table 4 summarizes these habitat associations.

Table 4. Significant variables from uni-variate analyses that indicate grizzly bear selection (+) or avoidance (--) of specific habitat characteristics. These variables were consistently selected or avoided across all study areas within this project.

Selection Variable	**sign**	**Avoidance Variable**	
		roads	--
elevation	+	highways	--
avalanche	+	human development	--
alpine	+	deciduous forest	--
slope	+	lodgepole pine	--
terrain ruggedness	+	cedar-hemlock	--
old forests	+	young forest	--
Douglas fir	+	curvature - wetness	--
greenness	+	riparian	--
park	+	riparian-roads	--
riparian-park	+	forest age	--
		greenness-human develop	--
		greenness-highways	--

The best models within each study area (Table 5) were combined into multi-scaled models for each GBPU (Fig. 4). The classification accuracy of our models was generally good ranging between 0.67 and 0.84. Where we had GPS radio telemetry locations, we found that our best DNA-derived multi-scale model predicted the habitat use of radio collared grizzly bears reasonably well. The binned model scores for the DNA hits and GPS radio locations were correlated (Spearman's rank correlation, 0.92).

Table 5. Variables and coefficients for the multi-variate models for each study areas at all 3 scales. PSA is Purcell South Area that includes the Yahk and south Purcell GBPUs, the PNA, the Purcell North Area includes the Central Purcell GBPU, and the SS is the South Selkirk GBPU.

PSA S1

Var	Coef	p
decid	-3.455729	0.051
rlog	3.964161	0.03
ofor	5.120177	0.013
road x ofor	-76.61629	0.002
green	3.171877	0.018
green2	-0.0105179	0.018
tri	0.027061	0.014
constant	-241.3534	0.017

PNA S1

Var	Coef	p
road	-22.4488	0.004
lpine	-5.36566	0.061
yfor	7.282218	0.074
yfor2	-15.9006	0.045
constant	0.361149	

SS S1

Var	Coef	p
aval	29.92909	0.022
cti	305.497	0.013
cti2	-21.5285	0.014
cc	0.237233	0.016
constant	-1092.11	

PSA S2

Var	Coef	p
road	-38.38919	0.006
road2	134.7026	0.015
green	4.654343	0.019
green2	-0.0155847	0.018
hop	-10.94788	0.022
age	-0.072429	0.012
constant	-340.8867	0.023

PNA S2

Var	Coef	p
alpine	92.23757	0.012
alpine2	-156.334	0.011
age	-0.26971	0.003
age2	0.003081	0.002
rip-park	124.7762	0.001
lpine	-6.03076	0.011
constant	-8.23042	

SS S2

Var	Coef	p
ofor	13.13757	0.002
dfir	-100.269	0.019
dfir2	299.4782	0.01
rip-park	406.1594	0.008
green	11.15206	0.061
green2	-0.03771	0.065
constant	-820.451	

PSA S3

Var	coeff	p
age	-0.132973	0
hop	-18.95928	0
cc	-0.3147559	0.006
constant	19.69139	0

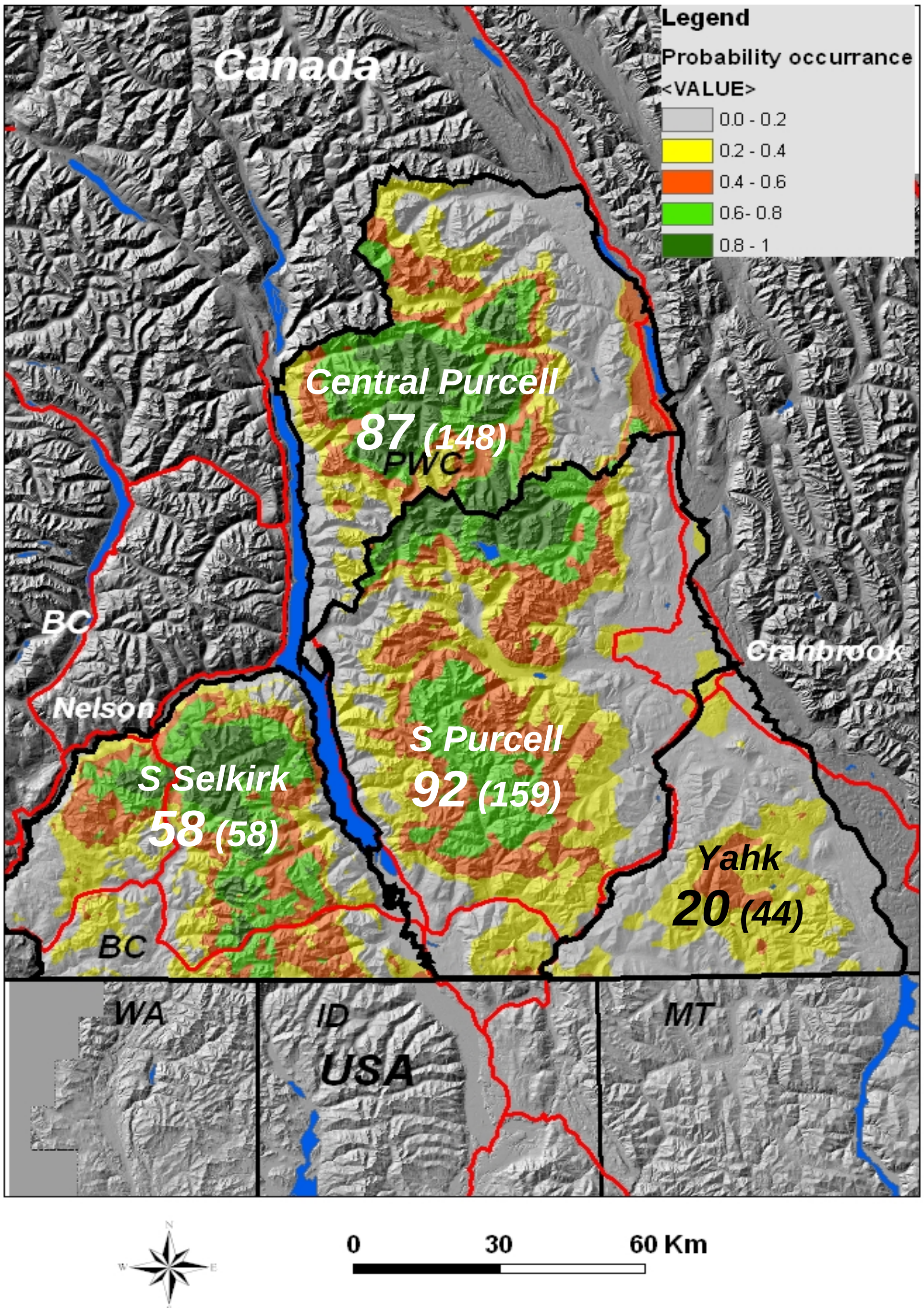
PNA S3

Var	Coef	p
road	-30.3703	0.008
lpine	-7.43301	0.081

SS S3

Var	Coef	p
rip	-123.044	0.015
green	25.31754	0.001
green2	-0.08624	0.001
cti	3.590039	0.011
dec	61.39468	0.045
constant	-1880.42	

Figure 6. Multi-scaled probability of occurrence models and population estimates for the South Selkirk, Central Purcell, South Purcell and Yahk GBPUs. The closure corrected and model extrapolated estimates are the bold numbers (58, 85, 88 & 20) and the number below them in parentheses are the BC Provincial estimates, prior to this analysis.



The closure corrected and model extrapolated population estimates for the Selkirk and Purcell GBPUs is summarized in Table 6. Our DNA survey-derived abundance and density estimates were considerably lower than official Provincial estimates used for setting hunting quotas (Table 7).

Table 6. Closure corrected and ecological model-extrapolated population and density estimates for 4 Grizzly Bear Management Units in southeast BC.

GBPU	Area km^2	Density GB / $1000km^2$	Density 95% CI	Pop Est GB	Pop Est 95% CI
Yahk	2719	7.2	5.7 - 9.0	20	16 - 25
South Purcell	6898	12.7	10.0 - 16.5	88	69 - 113
Central Purcell	4619	18.3	14.2 – 25.3	85	65 - 117
South Selkirks	4070	14.3	12.2 - 17.1	58	50 - 70

Table 7. New population estimates compared to BC provincial population estimates and the relationship to capability (how many bears can the GBMU contain under current conditions)

GBPU	Pop Est GB	BC estimate GB	BC capability GB	BC % of Cap	This report % of Cap
Yahk	20	44	101	44%	20%
South Purcell	88	159	198	80%	44%
Central Purcell	85	148	162	91%	52%
South Selkirks	58	58	131	44%	44%

Discussion – population estimation

Our estimates of abundance and density for the Purcell Mt. GBPUs were considerably lower than BC Provincial estimates (Table 8). Historically, BC Provincial estimates were generated from the Fuhr Demarchi (1990) method that relied on managerial application of qualitative assessments of habitat quality, disturbance, land use changes, and mortality history relative to one of two benchmark populations. More recently, most GBPUs are estimated from a province-wide multiple regression modeling exercise with an increased number of benchmark populations (from recent DNA surveys and other research; Mowat et al. 2004) and these include the Yahk, S Purcell, Central Purcell GBPUs (Hamilton et al.2004). In some GBPUs an improved expert Fuhr Demarchi estimate is used (i.e. the south Selkirk GBPU, Hamilton et al. 2004), and in others direct DNA inventory estimates, as reported here, are used. We suggest that due to the discrepancy in the Provincial estimates for the Yahk, South Purcell, and Central Purcell GBPUs (Table 8), our DNA survey-based estimates should be used (in fact our estimates have been incorporated as official Provincial estimates. G. Mowat, Nelson regional BC Provincial biologist, pers. comm.). Population-specific estimation data is usually preferable to extensive extrapolations. Our estimates result from 5 years of DNA survey effort within the target area where the need to extrapolate based on habitat was minimal. While not all grid estimates were done with population estimation as a primary goal, all surveys were designed to have standardized field methods. The only difference among surveys was the sampling intensity.

Our results do not suggest that BC provincial population estimates of grizzly bear population size are in general systematically too high. Boulanger and Hamilton (2001) examined the relationship between grizzly bear population estimates derived from the recently developed DNA survey method (Woods et al. 1999) and the BC Provincial Fuhr Demarchi (1990) method. In a comparison using 9 DNA projects, they found that on average, the estimates from each method were not statistically different even though there were significant differences in specific areas. This suggests that historic population estimates for setting hunt quotas across BC were reasonable. To be clear however, the estimates presented in this report represent the best science-based estimates for the GBPUs studied. Furthermore, improvements have been demonstrated in our ability to carry out DNA surveys in recent years yield population estimates that have better precision and minimal bias. (Boulanger et al. 2005, 2006; Proctor et al. 2007b).

Habitat selection, as determined by our ecological modeling, was found to be similar to that in other habitat modeling efforts for grizzly bears. DNA surveys were primarily conducted in June and July, therefore our modeling results reflect bear habitat use during those months. Apps et al. 2004 working in Columbia Mountains of BC, also modeled habitat in relation to DNA survey results and found avoidance of human features including roads, highways, and human developments with selection for rugged remote terrain, older forests, alpine, and avalanche habitats. Mace et al. (1996) used VHF telemetry data from northwest Montana as a basis for modeling habitat use and found similar patterns, concluding that while bears can persist in areas with roads and human activity, avoidance and mortality will increase as human access and development increase. The Mace et al. (1996) work underpins the US-wide (where grizzly bears persist) legal mandate for access management standards in “recovering” grizzly bear populations. These region-wide patterns that were also found to hold true across our two mountain ranges may hint at the causes for the lower than expected estimates in the Purcell Mountains.

However, before firm conclusions can be drawn, more specific work is required on road densities, “core” habitat (habitat away from roads), and their relation to grizzly bear habitat use and mortality risk within these study areas (Nielsen et al 2004a, 2006). Our research team has begun such efforts and several hypotheses will be explored ranging from systemic biases in historic estimates to increased human access to excessive hunting quotas.

The major advantage of our model-based extrapolation used here is that it starts from an extensive dataset of local grizzly bear ‘capture’ events and yields a far more ecological-based realistic extrapolation. The historic alternative of applying densities where surveys took place, often in areas where bears are more abundant, to the edges of GBMUs where abundance is often diminished, especially in populated areas like the Purcell and Selkirk Mountains, is likely to result in an over-estimate of grizzly bear population.

Although our approach was an improvement over other estimates, some limitations should be considered. First there was an increased chance in the two larger cell-sized projects (where sampling sites were not moved) in the Purcells that some females were not detectable (i.e. 0 capture probability) potentially creating a negative bias in estimates (Boulanger et al. 2006). However, the degree of bias is unlikely to be high enough to make our estimates of the same magnitude (approximately twice) as the BC Provincial extrapolated estimates. Second, we assumed that no error was introduced into population estimates by RSF-based extrapolation. In reality, error was introduced with ecological modeling. However, no method to estimate error rates from multi-scale RSF models had been developed. Therefore, the precision of our estimates is expected to be slightly lower than we have indicated. Third, we assumed that the population size and density of these areas was relatively similar which allowed us to consider estimates from different years. Regardless, we feel that locally-derived, habitat-based extrapolations should replace extensively extrapolated estimates whenever they are available.

The Yahk and South Selkirk GBPUs are considered “threatened” by the BC Province by virtue of being estimated at below 50% of their habitat capability (Hamilton et al. 2004). Current Provincial estimates of the relationship between habitat effectiveness (current bear numbers) and habitat capability (potential bear numbers habitat could contain) for the south Purcell GBPU is 80% while the Central Purcell GBPU is 91%, the Yahk GBPU at 29%, and the Selkirk GBPU is 65% (Table 8). Our population estimates suggest these values are considerably lower with the South Purcell GBPU at 44%, the Central Purcell GBPU at 49% the Yahk GBPU at 20%, and the S. Selkirk GBPU at 44% (Table 8). These numbers are relevant because they underpin the Provincial management approach applied to

GBPUs. GBPUs with high values can typically sustain human-caused mortality and are less likely to be driven to threatened status (below 50% capability; Austin et al. 2004). GBPUs with values approaching 50% should be managed more conservatively and may require management designed to increase population size to maximize future hunting quotas. Provincial determination of the conservation status of the South and Central Purcell GBPUs should be considered.

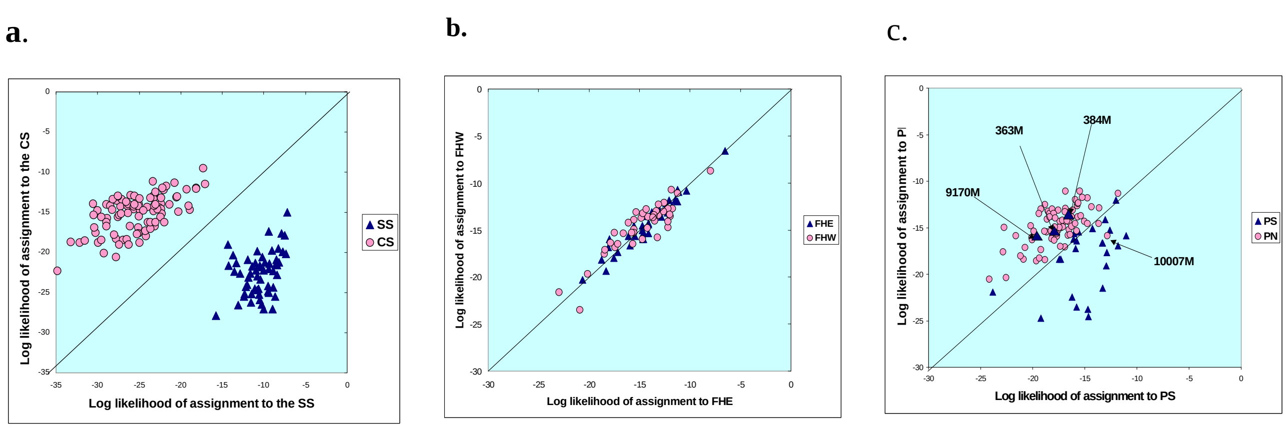
Of particular note is that the entire study area has considerably fewer bears than suspected or expected. These mountain ranges hold peninsular populations within a fragmented regional population (Proctor 2003, Proctor et al. 2005), as shown by the breaks across and between mountain ranges in our probability of occurrence model (Figure 4). The southern tip of the population south of BC Highway 3 has been shown to be fragmented (Proctor et al. 2005) and declining (Wakkinen and Kasworm 2004). The future persistence of the south Purcell and Yahk GBPUs (and into the US) is likely reliant on being connected to a healthy grizzly bear population in the Central Purcells. While the PNA was still below expected, the PWC (~2000 km^2) has a relatively high density of grizzly bears. This protected area has the potential to act as a source population for the surrounding area and assist in the recovery of the Central Purcell, South Purcell, and Yahk GBPUs. This logic follows the stated management intention of the BC MoE to manage for regional source populations (Austin et al. 2004**;** Peek et al. 2003). The good news is that there is a mechanism to modify rates of human-caused mortality by adjusting hunting quotas.

Our study demonstrates the need to periodically assess the status of hunted grizzly bear populations using methods that are based on local capture data, and not completely rely on correlates of abundance derived from distant times or locations. This need holds true particularly in areas where other human-related pressures are likely to impact bear populations, (high human access, road densities, etc.), and particularly along the fringe of the species range where population fragmentation and decline has led to dramatic loss of range in the past (McLellan 1998). BC is vast and grizzly bears occupy approximately 75% (750,000 km^2) of the Province, therefore, not all population can be realistically monitored. However, key areas of the province, where humans and grizzly bears extensively overlap should be considered for periodic surveys of grizzly bear abundance.

Chapter 2 - Linkage enhancement

As mentioned earlier, the S. Selkirk and S. Purcell/Yahk grizzly bear populations are fragmented. The Selkirk population appears to have recently gone through a period of complete isolation as the genetic signature for grizzly bears living in the ecosystem suggests that there has been no genetic interchange in the recent past (Fig. 7a; Proctor et al, 2005). Contrast the genetic assignments of bears across the unsettled but larger Flathead Valley in the Canadian Rocky Mts. where bears appear to be interbreeding completely (Fig. 7b). The South Purcell/Yahk population is partially fragmented, and appears to have a reduced number of male bears moving across BC Hwy 3 (Fig 7c). The dearth of female migrants has serious implications for both populations because from a demographic perspective, it is females who have the ability to functionally augment a population as females have the ability it increase a population through reproduction. Both the South Selkirk and S Purcell/Yahk populations are in need of functional connectivity to enhance their potential for long-term persistence and ultimately self-sustaining status.

Figure 7. Population assignments of grizzly bears in SW Canada and NW United States across BC/Alberta Highway 3 in three mountain ranges and one control system. Individuals highlighted by an arrow are likely migrants across Highway 3. M = Male and F = Female. a. South Selkirk Mts, b. Flathead River (control system) and c. Purcell Mts. population assignments. Adapted from Proctor et al. (2005)



While demographic forces are likely more important that genetic issues, the S. Selkirk population has reduced genetic variability (heterozygosity of 0.54) while all neighbouring populations, including the S Purcell/Yahk populations have similarly higher genetic variability indexes (heterozygosity = 0.66). indicating at least male mediated geneflow among populations except the S. Selkirks (Proctor et al. 2005).

To enhance inter-population exchange of grizzly bears with these two populations our project is working on identifying the best options for "linkage zones" across Highway 3 and 3A in the Purcell and Selkirk Mts. Because there appears to be some male interchange occurring across Highway 3 in the Purcell Mts., it is feasible to identify and further develop linkage zones in appropriate areas that would facilitate the secure movement of animals of both sexes through these human transportation corridors. As human development in the area proceeds, the opportunity to establish linkage zones across the Highway 3 and 3A transportation and human settlement corridor is diminishing every year. We used three techniques to identify linkage zones,

1) a variation of RSF modeling that uses systematic DNA survey results to estimate core and linkage habitat (Manley et al 2002; Apps et al 2004).
2) GPS radio telemetry to identify where bears (likely males) are actually crossing Highway 3 and 3A.
3) Resource Selection Function (RSF, Manley et al. 2002) modeling using GPS radio locations to predict linkage habitat.

The reason for using multiple methods is that it in a system where bears are sparse and movement across Highways 3 and 3A is limited, each method will reveal an important part of the picture, and hopefully together they will reveal the best options for linkage habitat.

RSF models have been used for predicting grizzly bear occurrence and habitat use in relation to many types of ecological and management questions (Mace et al. 1996, 1999, Boyce and Waller 2000; Nielsen et al. 2002; 2004a; 2004b; 2006) including ones very similar this effort.

Here we briefly report the methods and results from the 3 efforts.

Methods - linkage

DNA survey RSF modeling

In 2004 and 2005 we did DNA surveys of wild grizzly bears between Creston and Cranbrook BC and combined these results with those of a less intense but broader-based DNA survey in 2001 to underpin our DNA RSF analysis. DNA survey methods were identical to those reported in the previous section on population estimation, as surveys were used for both purposes, population estimation and linkage zone predictive modeling. Here we provide a brief outline of those methods.

For this work we used DNA surveys that were carried out in 2001, 2004, and 2005 in the south Purcell and Yahk GBPUs. In total, we sampled 170 sites within the study area, where we recorded the number of bears captured at each site over a 2 month survey. In a multiple logistic regression we correlated the detection of bears with several with ecological, terrain, forest cover, and human-use variables (Table 4) to predict grizzly bear occurrence across the whole study area (Manley et al. 2002; Nielson et al. 2002; Apps et al. 2004). Because grizzly bears select habitat and home ranges at multiple scales (Johnson's 1980; Manley 2002; Apps et al, 2004; Nams et al 2005) we modeled each GBPU at 3 scales as in Apps et al. (2004). The finest scale (Scale 1) was characterized by averaging each variable over a 2.4 km radius, the ~ average daily movement of a grizzly bear (B McLellan unpub. data). The medium scale (Scale 2) averaged each variable over a 6.8 km radius (~ female home range size) and the coarse scale (Scale 3) was over an 11.2 radius (~ male home range). Our final models represented a multi-scale analysis. For each scale we assessed collinearity of explanatory variables and removed one of the two correlated variables when Pearson's correlations where >0.7. Univariate analyses relating the detection of grizzly bears against each explanatory variable were tested and recorded for significance. All significant ($p < 0.1$), uncorrelated variables were considered during multivariate model development. We used the principles of Hosmer and Lemeshaw (1989) for model building where individual variables were added sequentially based on their univariate level of significance (from most significant to least significant), retaining only those variables that were significant ($p<0.1$) in the multivariate model.

GPS radio collaring

Since 2004 we have put out 11 GPS radio collars on grizzly bears in the Canadian portion of the Purcell/Yahk ecosystem. Most collars have been designed to stay on bears through 2 non-denning seasons (although 3 were for only 1 season) and take hourly GPS locations. Collars are programmed to automatically drop off in the fall of the 2nd season at which time we retrieve them and download the data. Several collars allowed uploading on a monthly basis while remaining on the animals. All capture work was carried out in accordance with Canadian Council on Animal Care. We put radio collars on 8 males and 3 females (one female was captured and collared by Jesse Lewis during a black bear project in NW Idaho).

Radio telemetry RSF modeling

The radio telemetry RSF habitat model is a spatially explicit multiple logistic regression integrated with GIS (Manley et al. 2002; Nielsen, et al. 2002). It associates grizzly bear habitat use as determined through GPS radio telemetry locations, with ecological, terrain, forest cover, and human-use variables (Table 4) to predict grizzly bear habitat use across the whole study area (Nielson et al. 2002). Variable data was obtained from a variety of sources, including, BC government Ministry of Forest TRIM (Terrain Resource Information Management), BTM (Baseline Thematic Mapping), VRI (Vegetation Resource Inventory data). The highway and human occurrence points (developments) layers were digitized from 1:50,000 topographic maps and ortho-photos, greenness was derived from Landsat imagery using a TassleCap transformation (Crist and Ciccone 1984), and slope, solar radiation, and terrain ruggedness were derived from a digital elevation model. Data was modeled at the100m x 100m pixel size.

The cumulative radio collar data were used to develop preliminary resource selection function (habitat use) models for the study area. The models are preliminary because we continue to radio collar bears and improve our sample size. Because it is preliminary we elected to pool all sexes and individuals into 1 model for each season. We defined 2 seasons as pre-berry – den emergence until July 14, and berry – July 15 until den entrance. We withheld 20% of the locations to validate each season's models (Hosmer and Lemshaw 1989; Boyce et al. 2002; Nielson et al. 2002). We compared grizzly bear telemetry locations (use) to an equal number of random locations (availability). Model selection followed protocols in Hosmer and Lemshaw (1989).

Model validation

We tested the ability of our DNA survey-derived models to classify the DNA occurrence results using a confusion matrix (McGarigal et al. 2000). We determined a cut-off probability (a threshold score where the model predicts the occurrence of a bear) using a sensitivity/specificity analysis (Liu et al. 2005). The cut-off probability was then used to classify presences of grizzly bears. A confusion matrix was generated and the overall classification accuracy determined as the ratio of correct classifications (absences and presences) to the total number of classifications.

Because we have radio collared bears in the Purcell south study area, we validated our best multi-scale DNA model using GPS radio location data. Here we used a Spearmans's rank correlation test (Sokal and Rohlf 1995) to compare the similarity of our model in predicting DNA captures (that were used to build the model) and independent GPS radio location data for the same area. The correlation test was preformed on the two data sets where RSF scores were categorized in equal bins and adjusted for area (Boyce et al. 2002).

To validate our RSF models derived from GPS data we built our models using 80% of our GPS locations and tested their predictive ability using the remaining 20% of the data (Boyce et al. 2002). This was accomplished in a similar fashion as described above testing for correlations between binned and area adjusted RSF scores (Boyce et al. 2002).

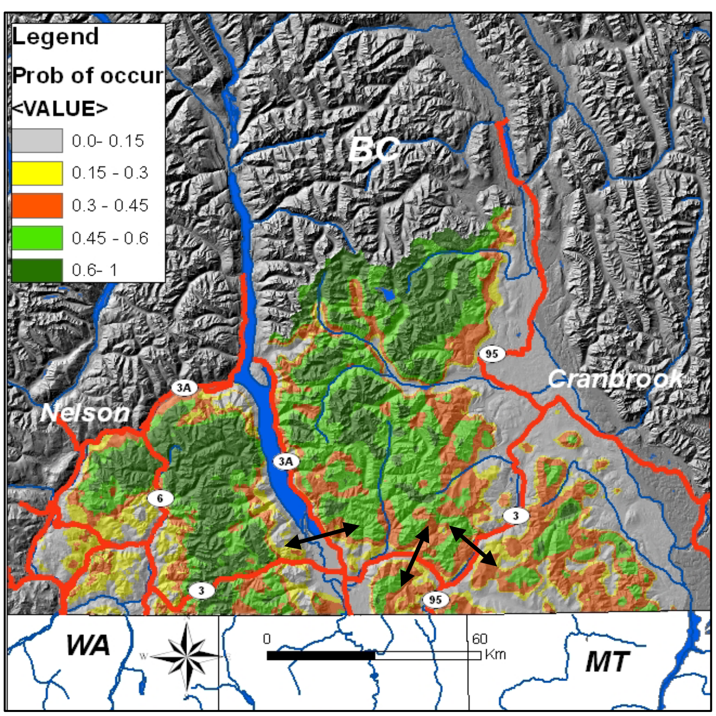
Results – linkage

DNA survey linkage models

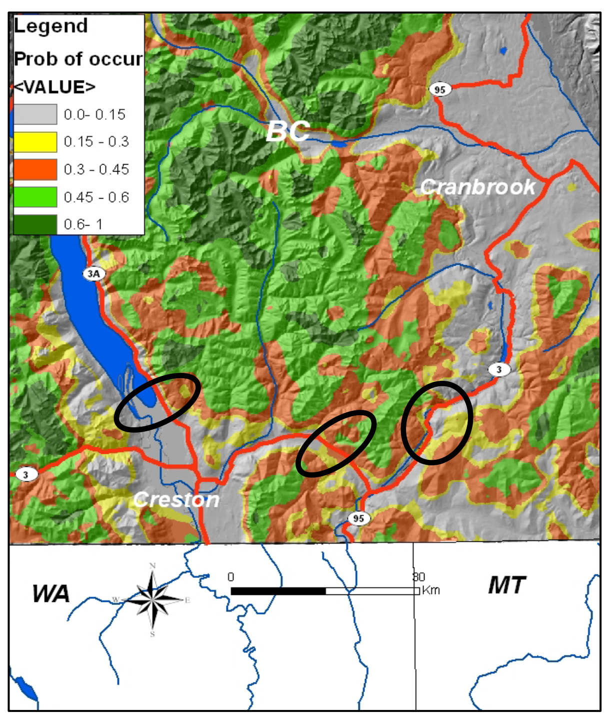
In total (in the 2001, 2004, and 2005 surveys) we captured 65 individual grizzly bears with multiple captures for many individuals totaling 124 capture events. These captures occurred at 55 of our 170 sampling stations. Our best regional multi-scaled predictive linkage models identified 2 general linkage zones along BC Highway 3 and one between the Selkirk and Purcell ranges (Fig 8a & b).

Figure 8. DNA survey and ecological modeling estimated linkage zones across BC Highway 3 in the Purcell Mts, and BC Highway 3A between the Purcell and S Selkirk Mts. a) is a view of both ecosystems and arrows indicate linkage zones. b) close up of model predictions suggesting linkage habitat (black ovals).

a)



b)

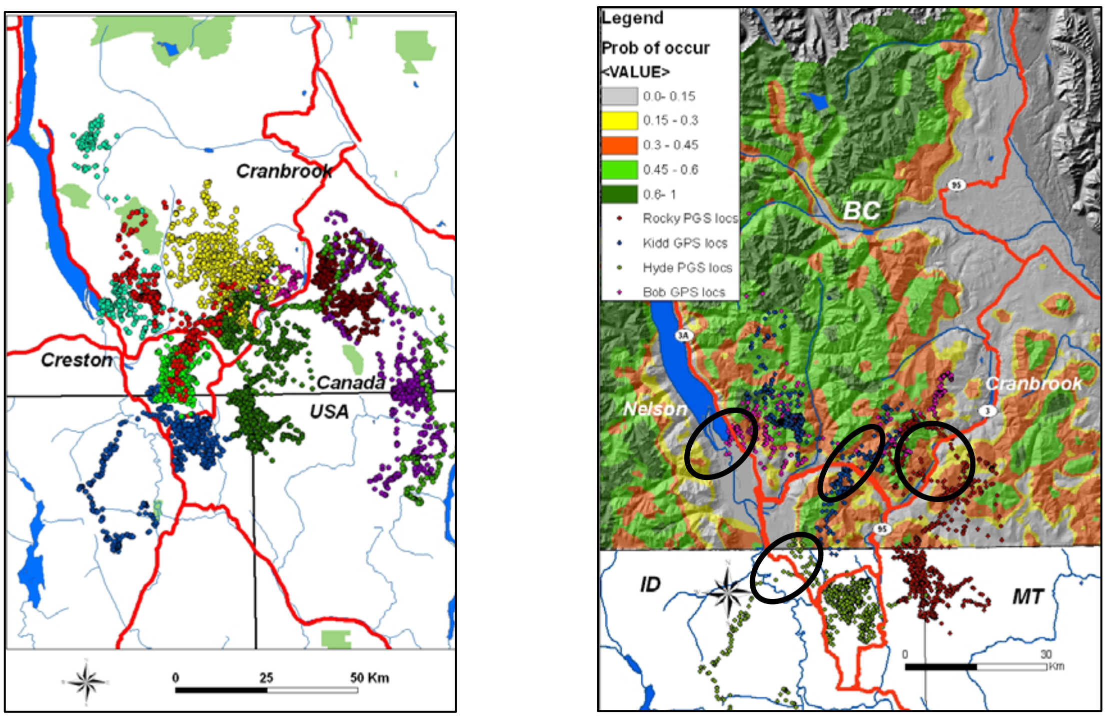


Radio telemetry

We retrieved GPS location data from 11 grizzly bears along BC Highway 3 between 2004 – 2006. In total we had over 18,000 bear locations (Fig. 8a). We have 2 male grizzly bears that have crossed BC Hwy 3 in the Purcell Mts., one that has moved between the south Purcell and south Selkirk ecosystems, and one that has moved across BC Hwy 3A in the Duck Lake area to forage in early spring (Fig. 9b).

Figure 9. GPS radio locations from grizzly bears over 3 years (2004 – 2006). a). Eleven bears, b) 3 males that cross highways within Canada overlayed with DNA-derived linkage habitat predictions. A 4th bear crossed in the USA (black oval), modeling is not complete for that area.

a). b)



Radio telemetry RSF modeling

For the spring season within a multiple logistic regression, our best model found elevation, greenness, alpine, roads, and Doulgas fir forests to be significant and positively correlated to bear habitat use and human development, old forests, and terrain ruggedness to be negatively associated with grizzly bear habitat use (Table 9). For the summer season we found elevation, greenness, alpine, Douglas fir forests cover to be significant and positively correlated with GB habitat use while human developments (buildings) old forests, avalanches, and terrain ruggedness were negatively correlated with grizzly bear habitat use. (Table 3). For multi-season fine-scale linkage zone identification we present a combined spring/summer habitat selection map (Fig. 10). Figure 11 displays the identical map with GPS locations for 4 bears that crossed Highways 3 and 3A.

In the model validation process, the training model (built from 80% of locations) was highly predictive of the remaining 20% of locations (Fig. 6). Mean RSF scores in each data set were essentially identical at 0.621 and the predictive ability of bear locations across the range of habitat quality was highly correlated.

Figure 10. Linkage habitat as predicted by a Resource Selection Function (RSF) derived from GPS radio locations of 11 grizzly bears. Map is a composite of a spring and summer RSF models. Note the fine scale predictions as to linkage habitat across Highways 3 and 3A.

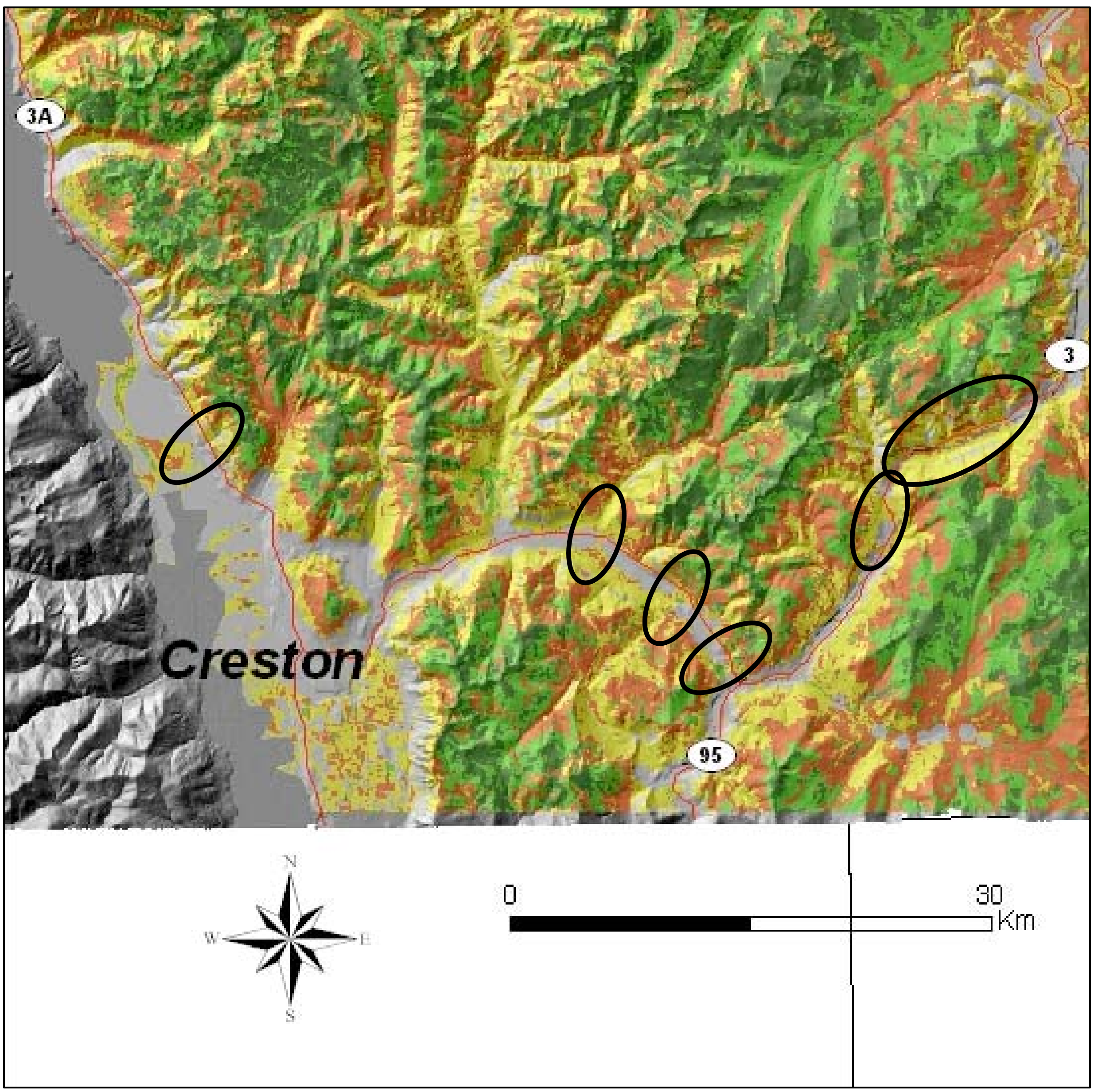
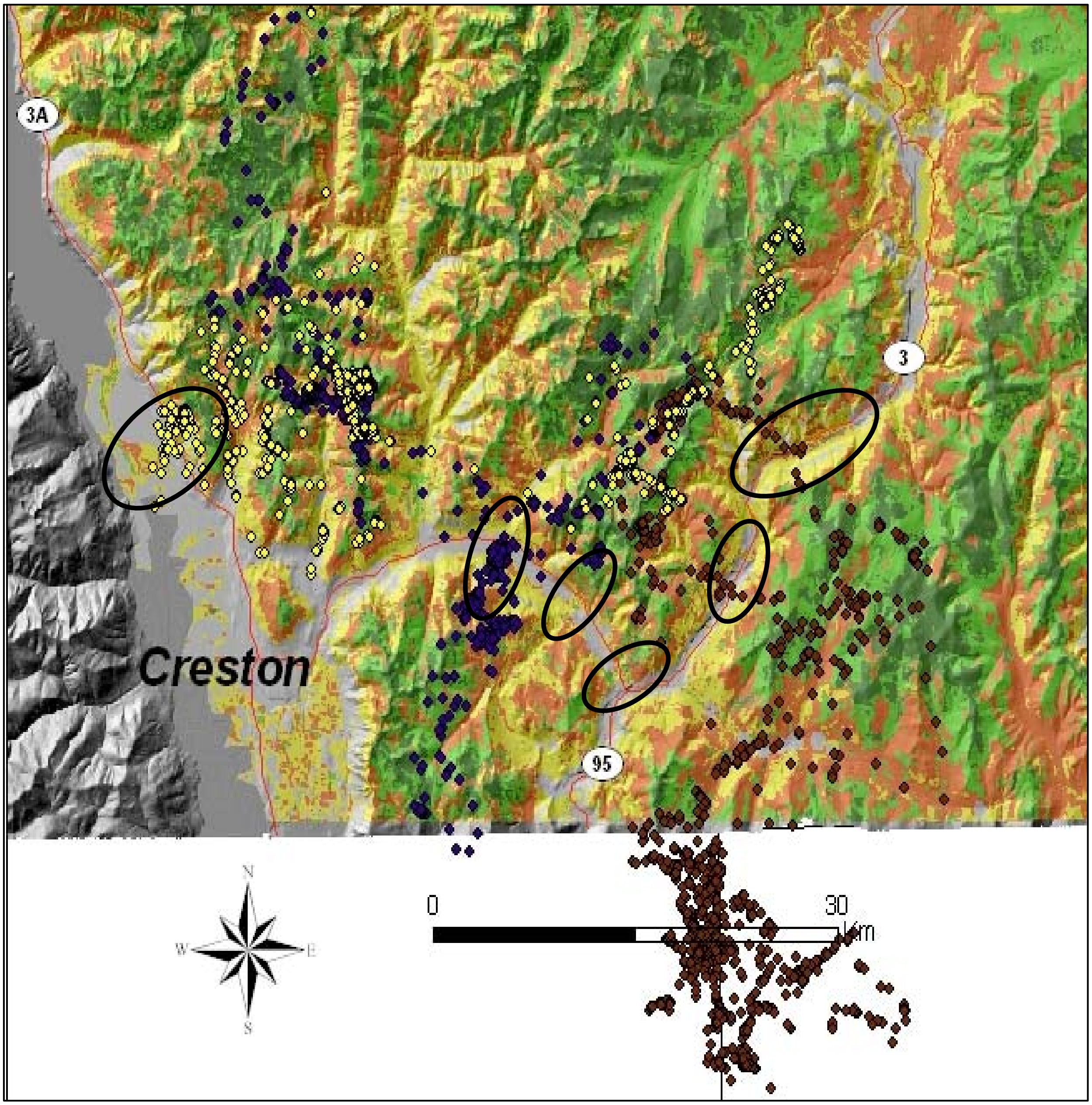


Figure 11. Identical map as in Figure 10 - predicted linkage habitat from GPS locations of 11 grizzly bears with actual GPS locations from 3 males that crossed Hwy 3 and 3A.



Discussion - Linkage

We used three methods to identify potential linkage zones along highway 3 and 3A because bear densities are low and movement across the highway corridors is limited making them challenging to detect, characterize, and predict. The fact that our model predictions are corroborated by movements detected by GPS radio collar locations encourages us to feel confident that habitat variables are playing a role in these remnant secure locations where bears can move through human dominated environments and survive. Our goal is to use bear habitat models and movement data to predict relatively secure linkage habitat where we can apply concerted management to maintain and further improve security allowing inter-population movement of bears. As expected, all our crossings are male bears. Our ultimate goal and need, is to secure linkage habitat such that population enhancing females occasionally move across the highway/settlement corridors. This expectation is not unrealistic. Recent genetic analyses (not presented in this report) indicate a recent female migrant across Highway 3 in the Purcell Mts. We put a radio collar on this particular female and when she was 5-6 years old she was shot by a landowner within 500m of Hwy 3, potentially moving back to her natal area north of Hwy 3. Research by Proctor (2003) suggested that human-caused mortality is one of the primary factors driving fragmentation in this system. Reduction of bear attractants simultaneously improves several management problems impacting this ecosystem. It should reduce human-bear conflicts, reduce human-caused mortality and thereby increase productivity and ultimately population size, and allow a modicum of inter-population movement.

We have begun management actions designed to improve security within the identified linkage zones. First we have shared these locations with the local timber industry that has integrated them into their timber plans. We have also provided appropriate management guidelines on road, timber harvest, and silvaculture protocols when within linkage zones. Our results have been shared with government biologists who have integrated linkage management into hunting regulations (see below). Furthermore, we have identified a few strategic lands that we are trying to purchase in partnership with BC Nature Trust, the Nature Conservancy, Vital Ground, and Yellowstone to Yukon Conservation Initiative. We are in the process of finalizing a comprehensive linkage management plan for the entire area.

Our research on linkage enhancement is not complete. We are encouraged by finding ecological patterns that allow reasonable predictions of linkage habitat. However, we must interpret or results with caution as our sample sizes are low. Low sample sizes are a reality in compromised ecosystems and we strive to find a balance between inaction because our certainty is not perfect, loosing irreversible opportunities yielding to that uncertainty, and management action that may be inaccurate.

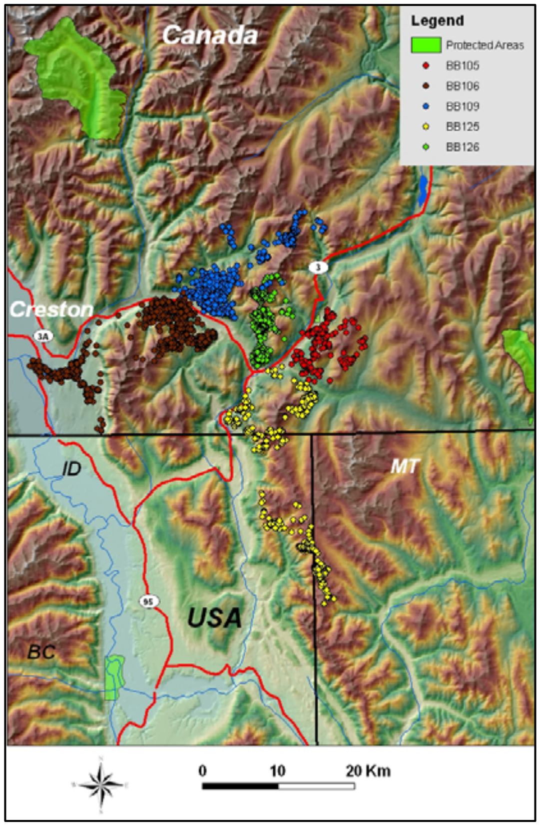
Black bear linkage research

In 2006 we began doing black bear research along BC Highway 3. In other linkage identification programs (Highways 2 in Montana and 95 in Idaho) we are forced to utilize black bears as surrogates for grizzly bears because of very small grizzly bear populations in the linkage area. Telemetry from black bears and grizzly bears in the same area may provide validation of the use of black bears as surrogates in other locations. In the BC portion of the Trans-border Grizzly Bear Project, we have the advantage of having both species of bears and therefore decided to do parallel research on black bears to test the hypothesis that black bears would be a reasonable surrogate for grizzly bear linkage research and management. Further impetus lies in the investigation of anthropogenic fragmentation of black bears as another large carnivore on the landscape as preliminary evidence suggests that highways and associated settlement may be also fragmenting black bear populations (Wayne Kasworm, pers. comm.). Because we are already carrying out grizzly bear radio collaring efforts, there is no extra effort to collar black bears (except the cost of the collars). From an analytical perspective the same advantage applies, most analyses can be carried out with black bear data with minimal extra effort.

Our specific research goals are to use GPS radio collar data to locate areas where black bears cross BC Hwy 3 (if they cross). We also plan to use the GPS location data to build RSF models to predict linkage and core habitat as we have done with grizzly bears (described above). This research is not to the point where we have analyzed our results, but here we report our progress to date.

In the spring of 2006 we put out 7 GPS radio collars. Collars were programmed to take locations every hour through October 15 at which time they fell off and we retrieved them. We have retrieved 5 of the seven collars and the resulting locations is summarized in Figure 12. One collar is still in a den (not on the bear) and we will retrieve it in the early summer of 2007. We cannot detect a radio signal for the 7^{th} collar and suspect it may be malfunctioning.

Figure 12. GPS radio collar locations for 5 black bears along BC Highway 3 in the south Purcell Mts.



Chapter 3 - Habitat Security

Our third area of research related to specific bear management strategies is to improve habitat security for grizzly bears. We need to understand the spatially explicit relationship of roads and human access to these important habitats. Many researchers have demonstrated that roads and access are generally inversely related to bear habitat use (Archibald et al. 1987; Mattson et al. 1987; Kasworm and Manley 1990; Wakkinen and Kasworm 1997; Mace et al, 1996, 1999; McLellan and Shackleton 1988). A fundamental principle of grizzly bear management in threatened populations is to understand and manage this aspect of human-bear relations. Bears can be displaced from high quality habitat near roads, and mortality risk is often increased when bears are attracted to high quality habitat that is near roads. We realize that the backcountry south Purcell road network is also a critical requirement of economic activity and recreation. Therefore, before any road management is considered or instigated, we need to understand the relationship between human needs and bear habitat needs. Optimization of that relationship may allow both species to prosper.

In threatened grizzly bear populations within the USA access management is a standard tool used to insure habitat security for female grizzly bears. That bears select habitat and have a reduced mortality risk in core habitat has been the subject of much literature (Mace et al. 1996; 1999; Wakkinen and Kasworm 1997) and is at the centre of habitat management in the US where it has survived scrutiny by government agencies (USFWS, USFS), environmental organizations, and timber companies (C. Servheen pers. comm.). The logic stems from work done by Mace et al. (1996; 1999) on grizzly bear habitat use in relation to roads. Habitat security is provided by insuring that within female home range sized Bear Management Units (BMU) some minimum percentage of habitat exists that is not within 500m of a motorized road ("core" habitat) and that some percentage of habitat has $< 1km/km^2$ of roads. On the US portion of the S Purcell/Yahk and S Selkirk ecosystems, Wakkinen and Kasworm (1997) determined that the at least 55% of BMU should be in core and 67% should have $< 1km/km^2$ of roads. This standard is a legal requirement on US Federal lands and has been integrated into land use realities by timber companies, the US Forest Service, and the public. The legal standard in the Northern Continental Divide and Yellowstone US Recovery Zones is 68% core and 67% $< 1km/km^2$ of roads.

These habitat security targets have been a primary management tool for recovery of the Yellowstone ecosystem and a main feature of the NCDE ecosystem. The Yellowstone system has seen a remarkable and documented recovery over the past 20 years (Schwartz et al, 2005; Pyare et al. 2005) while the NCDE (which is currently being assessed) is definitely experiencing a range expansion (C. Servheen pers. comm.). The Yahk/Moyie ecosystem has not experienced a similar recovery.

Within the Canadian portions of these ecosystems, it is our goal to use US habitat security targets as informative guidelines within Canada, where we will develop our own appropriate standards. This section covers our efforts to the improve grizzly bear habitat security by understanding the spatially explicit relationship between roads, access, and grizzly bear habitat use. We began by determining the current status of habitat security and road densities for the Canadian portion of the S Purcell/Yahk ecosystem. Then we used Resource Selection Function (RSF) modeling by correlating ecological, terrain and human-use variable to bear habitat use as determined through GPS telemetry (see Chapter 2). RSF models have been used for predicting grizzly bear occurrence and habitat use in relation to many types of ecological and management questions (Mace et al. 1996, 1999, Boyce and Waller 2000; Nielsen et al. 2002; 2004a; 2004b; 2006) including ones very similar this effort.

Methods - habitat

Radio telemetry work

Radio collaring methods have been described in Chapter 2, Linkage enhancement, (see Chapter 2, page 26).

Road, access, and habitat modeling

We carried out a GIS-based analysis of grizzly bear habitat and road access in the south Purcell Mountains. The ultimate goal is to develop a management plan that will optimize the use of roads by humans and habitat security by grizzly bears. We also developed preliminary resource selection function (RSF; Boyce and McDonald 1999; Manly et al. 2002; Nielsen, et al. 2002) models from 3 years of radio telemetry data to identify areas of high quality grizzly bear habitat (see methods on page 26). These areas were then analyzed for two aspects of grizzly bear management: core habitat and road density.

Here we sub-divided the area south of BC Hwy 3 to the US border within Canada into “bear management units” and characterized habitat in terms of the percentage of core habitat available to grizzly bears and road densities. Bear management units (BMU) were created to partition the area into units approximately equal to female grizzly bear home ranges. These units theoretically contain enough variable habitat to meet the annual needs of female grizzly bears. Each BMU was characterized as to the percentage of “core” habitat available and percentage of area where road densities are less than 1km/km^2.

We used radio collar data (GPS from this project and VHF from Kasworm et al. 2006) to establish BMUs. Because our radio collar coverage over the area is not complete and female home ranges often overlap, these data were only a guide in partitioning the area into BMUs, and we used professional judgment to create units that contained habitat that would meet annual requirements (spring, summer, fall, and denning habitat).

Core area was accomplished in a GIS environment by creating a 500m buffer around all roads and computing the percentage of area not contained within the buffered habitat within each BMU. Road density was determined by calculating a linear road density per each square kilometer and tabulating the percentage of each BMU with road densities less than 1km / km^2.

We envision that the ultimate process of implementing an access management plan in the area will be a multi-year process. Within each high quality habitat area we will eventually rank roads by their intensity of use, their importance to Tembec and other timber harvest interests, the public, and grizzly bears and develop a plan to optimize roads for consideration of access management actions to fulfill the Forest Certification process.

At this stage in our efforts to enhance habitat security we refrained from making recommendations as to specific roads that could be managed, as this effort is to initiate a process of access management. This report was meant to bring together biological data for grizzly bears that would be relevant for such a discussion.

Results - habitat

Radio telemetry

Radio telemetry results are identical to results reported earlier in Chapter 2.

Core habitat and road density

We developed 5 GBMUs (Fig. 13) that range in size from 300 to 800 km^2 (Table 9). The percentage of each GBMU that is “core” habitat for grizzly bears is almost uniform at approximately 35-40%, with the exception of the Cranbrook unit that is ~20% (Table 8, Fig. 14). The road densities are also similar across units with a range of 48-55% except for the lower Cranbrook unit at 34% (Table 8).

Figure 13. Bear Management Units for the Yahk / Moyie area south of BC Highway 3

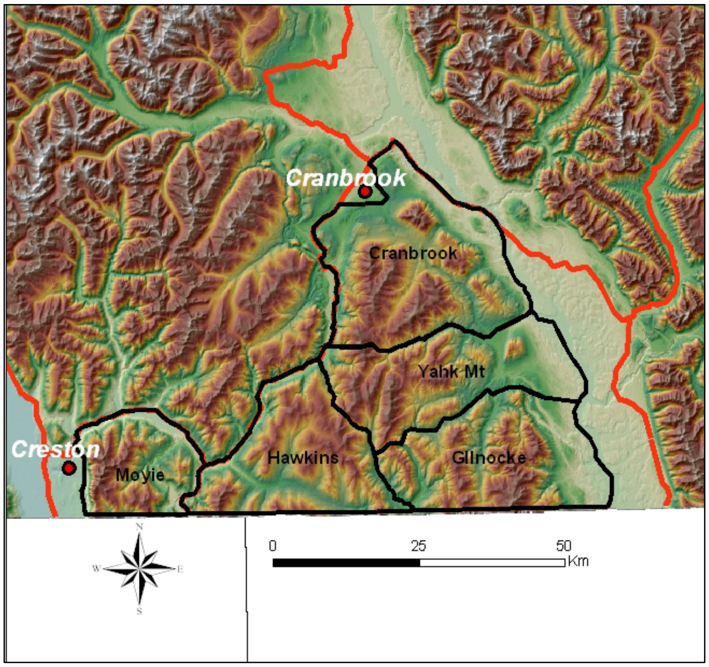
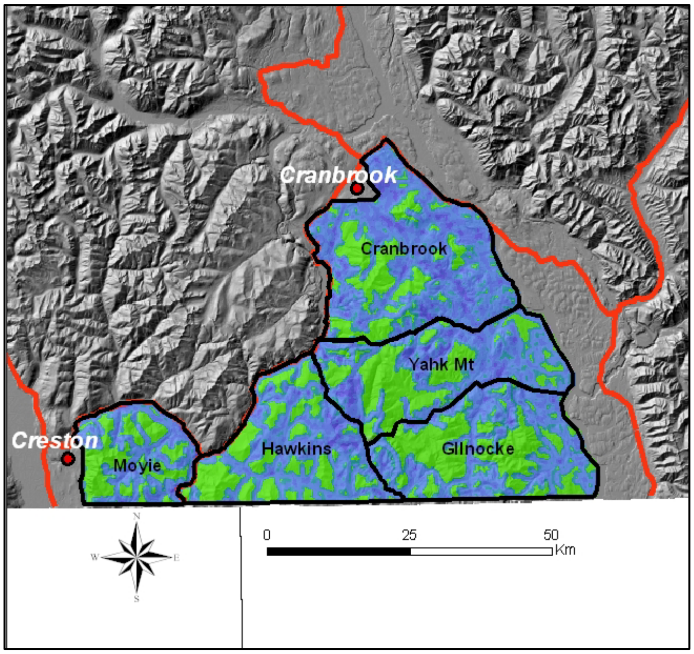


Table 8. "Core habitat" (area not within 500m of a motorized road) and road densities (%<1km of road / km^2 area) within grizzly bear management units south of BC Hwy 3 in the south Purcell Mts,

GBMU	area km^2	% core	%<1km/km2
Moyie	320	0.36	0.52
Hawkins	563	0.34	0.49
Gilnocke	622	0.39	0.55
Yahk Mt	584	0.34	0.48
Cranbrook	804	0.21	0.34

Figure 14. Grizzly bear core area within Bear Management Units (BMU). Green areas depict "core" habitat" that is not within 500m of a motorized road. Blue areas are areas within 500m of a motorized road. See Table 8 for % core within each BMU.



Resource selection function modeling

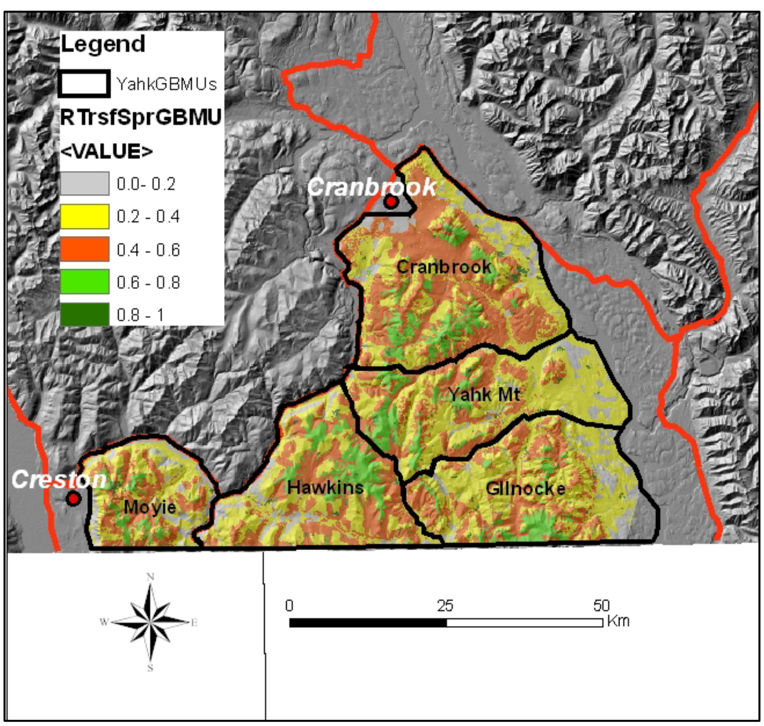
RSF models are identical as those described in Chapter 2 (see page 29) and here we display both spring and summer variables within our best multiple logistic models (Table 9) and a map representation within the context of the BMUs in Figure 15.

Table 9. Variables used in best GPS radio telemetry RSF models for spring and summer grizzly bear use in the south Purcell Mts.

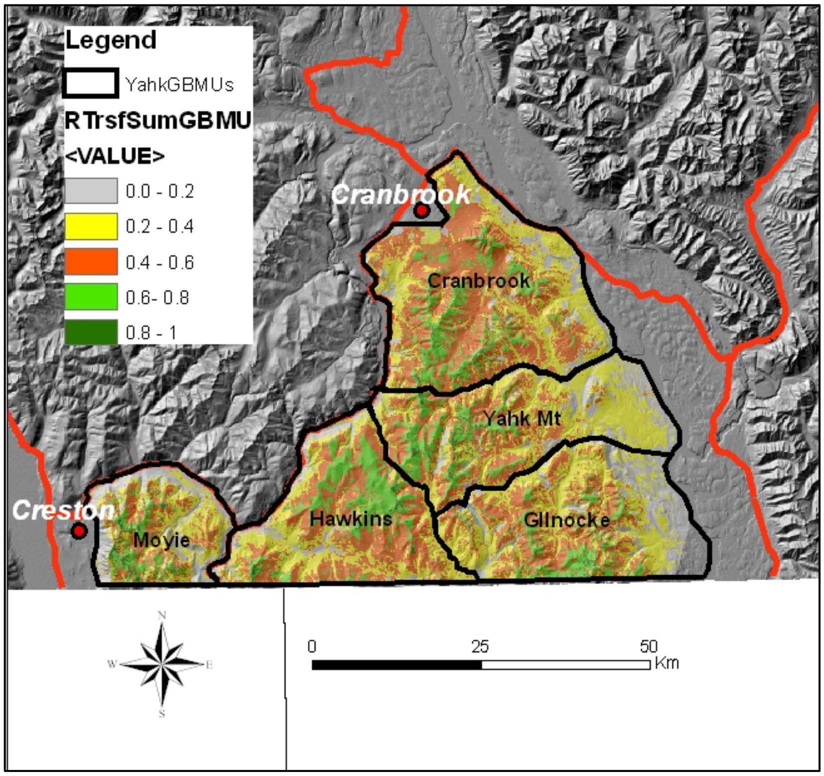
	Variable	Coefficient	sign
Spring RSF	**elevation**	0.0018097	+
	greenness	0.0188452	+
	spruce-sub alpine fir	0.4282923	+
	human development	-1.559778	-
	road	1.08553	+
	road_old forest	-0.5433421	-
	constant	-6.349319	
Summer RSF	**elevation**	0.0024032	+
	greenness	0.0382593	+
	human development	-1.381813	-
	alpine	0.5279438	+
	Douglas fir	1.294025	+
	old forest	-1.178526	-
	avalanche	-3.192643	-
	Terrain ruggedness	-0.0110546	-
	constant	-8.530121	

Figure 15. Resource Selection Function (RSF) habitat maps for grizzly bears in the GBMUs.

a) Spring RSF, den emergence to July 14



b) Summer RSF, July 15 to Den entrance



Discussion - habitat

We envision a discussion about enhancing grizzly bear security and access management between local stakeholders including timber companies, the Ministry of Forests, the Ministry of the Environment, local hunters and recreationists, and ENGOs. Our research is not complete but we are to the point where we have enough data to do preliminary analyses, and inform the initial discussion. Similar efforts in other jurisdictions teach us that developing access management plans that are accepted and respected by industry, government, and the public require that all effected parties be involved in the process and discussion leading to any land use decisions.

Variation in habitat selection between individual bears has been shown (Nielsen et al. 2002; Mace et al 1996) and is expected. Therefore sample size is a consideration when attempting to characterize habitat selection by a population of bears. Our sample sizes at this time are too small to allow individual-based sex-specific habitat selection models. For instance, we have data from only 3 females, and this would not be sufficient to characterize female grizzly bear habitat use. Previous studies have demonstrated that males and females do select habitat differently (Mace et al. 1996, Wakkinen and Kasworm 1997) and it is in the end, female habitat security that we are concerned with. While gratified that our validation method demonstrated the ability of one portion of our data to predict the remaining portion, our ultimate goal is to produce sex-specific seasonal habitat models built from cumulative individual RSF models. This report is an annual update of the progress we have made in year 3 of a 10 year project. Ultimately we will run these habitat selection models at the individual bear level and derive seasonal sex-specific predictive models.

The variables that we found to be significant and positively associated with bear occurrence, elevation, greenness and alpine, are consistent with expectations from other work as are the avoidance of human developments (Mace et al. 1996). Interesting though is the apparent avoidance of avalanche paths and rugged terrain (McLellan and Hovey 1995; Apps et al.. 2004). The likely explanation for the negative response to these variables that usually selected may be an artifact of their low occurrence in this particular ecosystem.

The almost uniform percentage of core habitat (~35% not within 500m of a motorized road) and the ~50% area with road densities < 1km / km^2 across the GBMUs is considerably lower than the thresholds used for grizzly bear management in recovering populations in the USA (Mace et al. 1996; Wakkinnen and Kasworm 1997). The Northern Continental Divide Ecosystem (NCDE) and the Yellowstone ecosystem have a biologically derived legal target of 68% core accompanied by 67% of the area of a BMU that has a road density < 1km / km^2. The US portion of the ecosystem reported here has a target of 55% core with 67 % road density < 1km / km^2 (Wakkenin and Kasworm 1997). These habitat security targets have been a primary management tool for recovery of the Yellowstone ecosystem and a main feature of the NCDE ecosystem. The Yellowstone system has seen a remarkable and documented recovery over the past 20 years (Schwartz et al, 2005) while the NCDE (which is currently being assessed) is definitely experiencing a range expansion (C. Servheen pers. comm.). The Yahk/Moyie ecosystem has not experienced a similar recovery.

In fact, the South and Central Purcell grizzly bear populations appear to be considerably smaller than was thought by government estimates (se abundance estimation Chapter 2). Our research team has begun efforts to explore why and several hypotheses will be considered ranging from systemic biases in historic estimates to increased human access to excessive hunting quotas.

There is work to be done in subsequent years to bring the access management discussion to fruition, First will be to integrate the intensity of use of roads and the prioritization of access requirements by industry and the hunting and recreational public. Second will be to include our final GPS radio telemetry data set. Third will be to bring together the parties required for a meaningful discussion. In subsequent years we intent to export this process to areas north of BC Hwy 3 in the Purcell Mts and into the Selkirk Mts.

Chapter 4 - Education and integration

Comprehensive "recovery" efforts such as this one require that all interested and affected parties take part in the development and implementation of the solutions. Loggers, hunters, farmers, landowners, and recreationists living and working in and around threatened grizzly bears populations must be part of the process for ultimate success to be attained. There are 7 groups that we strive to educate and integrate: 1) Government, 2) Industry, 3) Hunters, 4) Recreastionists, 5) Landowners, 6) Public 7) ENGOs. Here we briefly describe progress made in the integration process.

1. Government. We regularly meet with local and regional biologists and managers to discuss our research, its implications and what might be relevant to their management needs. We provide them with all our results in a timely manner. For instance we have submitted the Abundance estimation report (see Chapter 2) to government biologists and the population estimates we report were immediately incorporated into official population estimate for determining conservation status, setting appropriate hunt quotas, and altering population objectives for specific GBPUs. Specifically, the province has 1) re-drawing the legal hunt boundaries in the periphery of the threatened Purcell/Yahk populations to accommodate the recovery process, 2) created a no hunt buffer to allow for linkage recovery, and 3) used our research-derived population estimates for the Grizzly Bear Population Units (GBPU) that allows for accurate hunt quotas in GBMUS immediately adjacent to the threatened GBPUs. This is good evidence of a real working partnership between research scientists and science-based decision makers within government.

2. Industry. We have a close working relationship with one of the major timer companies (Tembec Industries) working in the Purcell/Yahk ecosystem within Canada. They are one of our significant funders, and we provide our results which they are integrating into their timber harvest protocols where appropriate. Besides integrating special management within identified high quality grizzly bear habitat, they are interested in being at the table for the future discussion of enhancing habitat security for grizzly bears.

3. Hunters. We perceive the hunting community as conservationists because of their interest in keeping the backcountry relatively wild. We share our results with this important and influential component of the public and have a uniformly positive response to good and fair science. One example is that when confronted with the fragmentation data surrounding the Purcell/Yahk grizzly bear population and the new population estimates, they voluntarily agreed to accept and respect reductions in the hunt quota, and the no hunt buffer being established in adjacent populations to contribute to recovery (G. Mowat pers.comm).

4. Recreationists

Our connection to recreationists to date consists of their attendance to our annual public presentations within each small community within our study area. We realize they enjoy their access to the backcountry and hope to enlist their support in future discussions of habitat security (access management). We have made contacts with leaders in this community.

5) Landowners

We make contact with landowners at a personal level each field season. We ask permission to explore their land looking for bear sign and share our project and results. Most who we make contact with, attend our annual presentation in their community. We also obtain valuable bear sighting information near highways from several landowners. They are often our entrance into a community, and we believe the presence of researchers in their communities builds tolerance and respect for our project goals and bears in general. We are just beginning to identify specific linkage zones, and will be moving forward with more intense education efforts within these to try and reduce bear attractants to an absolute minimum.

6) Public

We work for general public support for our project goals in several ways. We give annual public presentations and often have over 150 audience members. In one community (Yahk), the attendance was greater than the entire small population. We have periodic stories in the local newspapers, radio and cultural publications. Several times our project has made it to national radio, we were featured on Canada’s premier national science radio program, Quirks and Quarks.

7) ENGOs

Last but not least is the ENGO community, which we often rely on for financial support and implementation of strategic solutions. Several ENGOs have been long-term supporters, such as the Yellowstone to Yukon Conservation Initiative based Wilburforce Foundation who has contributed to our research over many years. At a more local level Wildsight has been supportive and uses our results in a science-based approach to conservation efforts.

We are very cognizant that research independence is the cornerstone to fair independent objective science and we strive for this type of relationship with all the groups we interact with throughout this effort. We easily integrate with government, industry, hunter groups and ENGOs all on the premise that our research is attempting to be as impartial and biological and possible. So far everyone respects that position and we feel that often we are the bridge between what are divergent interest groups working for their internal interests but that often have something in common with each other – a healthy natural environment.

Conclusions

This report has summarized our efforts to "recover" the threatened trans-border grizzly bear population in the south Purcell/Yahk and south Selkirk ecosystems within Canada. While the USFWS has been working towards this end for the past 15 years from within the US (Kasworm et al. 2006), this cooperative work, centered mainly in the Canadian portions of these ecosystems, began in 2004. This, our first annual report, really presents 3 years worth of progress in four realms of research and management: mortality reduction, linkage enhancement, habitat security, and education/integration.

Our mortality reduction efforts have included a spatially explicit analysis of the patterns of human-caused mortality and led to the hiring of a Bear Aware education specialist. Our population estimation work in the region has led to the redrawing of the legal hunt boundaries in the periphery of these ecosystems essentially creating a necessary buffer, and an improvement towards more accurate hunt quotas for the adjacent populations, an important step for reducing mortality and enhancing connectivity.

We have identified several "linkage zones" through DNA survey-based habitat modeling and GPS radio telemetry in which we intend to initiate management that will allow bears to move through human dominated environments with a decreased mortality risk. This effort includes purchasing strategic linkage habitat where necessary, working with the timber industry and government to manage linkage habitat appropriately, and to reduce bear attractants and thus mortality in linkage zones.

We are using our GPS radio telemetry data to build habitat-use models for grizzly bears that will be the basis for a community discussion of improving habitat security for bears through access management guidelines. This is a multi-year process and we have taken the first step of assessing the current state of habitat security and identifying high quality bear habitat. Next year we will assess human requirements for road use and through consultation with stakeholder groups, develop an optimized strategy to improve grizzly bear habitat security while optimizing human use of the backcountry road system.

All our strategies include education and integration of all appropriate stakeholders, including government, industry, hunters, recreationists, the public, and ENGOS. Bear management is really people management and that usually succeeds with maximum participation and meaningful input.

There are several jurisdictions around the world where grizzly bear recovery has been successful and all had comprehensive management strategies that were applied consistently but adaptively over an extended period of time and that considered the spectrum of forces impacting bear populations. It is our intention to emulate these successful programs with locally relevant solutions and a sustained yet flexible effort

Literature Cited

Apps, C.D., B.N. McLellan, J.G. Woods, and M. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management. 68:138-152.

Archibald, W.R., R. Ellis, and A.N. Hamiliton, 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. International Conference on Bear Research and Management. 7:251-258.

Austin, M.A. , D.C. Heard, and A.N. Hamilton. 2004. Grizzly bear (*Ursus arctos*) harvest management in British Columbia. British Columbia Ministry of Water, Land, and Air Protection, Biodiversity Branch. Victoria, B.C. 9 pp.

Boulanger, J. and A.N. Hamilton. 2001. A comparison of DNA mark-recapture and Fuhr-Demarchi / stepdown population and density estimates for grizzly bears in British Columbia. BC. Ministry of Environment. Victoria. BC.

Boulanger, J. and B.N. McLellan. 2001. Closure Violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology. 79:642-651.

Boulanger, J.B., G.C. White, B.N. McLellan, J. Woods, M. Proctor, and S. Himmer. 2002. A meta-analysis of grizzly bear DNA mark-recapture projects in British Columbia, Canada. Ursus. 13:137-152.

Boulanger, J., McLellan, B.N., Woods, J., Proctor, M.F., and Strobeck, C. 2004. Sampling design and bias in DNA based capture-mark-recapture population and density estimates of grizzly bears. Journal of Wildlife Management 68:457-469.

Boulanger, J.,G. Stenhouse, G. MacHutchon, M. Proctor, S. Himmer, D, Paetkau, and J. Cranston. 2005. Grizzly Bear Population and Density Estimates for the 2005 Alberta Unit 4 Management Area Inventory. Report Prepared for Alberta Sustainable Resource Development, Fish and Wildlife Division.

Boulanger, J., M. Proctor, S. Himmer, G. Stenhouse, D. Paetkau, and J. Cranston. 2006. An empirical test of DNA mark-recapture sampling strategies for grizzly bears. Ursus 17:149-158.

Boyce, M.S. and L.L. McDonald. 1999. Relating populations to habitat using resource selection functions. Trends in Ecology and Evolution. 14:268-272.

Boyce, M.S. and J.S. Waller. 2003. Grizzly bears for the Bitterroot: predicting potential abundance and distribution. Wildlife Society Bulletin31:670-683.

Boyce, M.S., P.B. Vernier, S.N. Nielsen, F.K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling. 157:281-300.

Bunnell, F.L. and D.E.N. Tait. 1981. Population dynamics of bears - implications. In, T.D. Smith and C. Fowler (Eds.). Dynamics of large mammal populations. John Wiley and Sons. New York. pp. 75-98.

Crist, E.P. and R.C. Ciccone. 1984. Application of the tasseled cap concept to simulate thematic mapper data. Photogrammetric Engineering and Remote Sensing 50: 343-352.

Fuhr, B., and D.A. Demarchi. 1990. A methodology for grizzly bear habitat assessment in British Columbia. B.C. Ministry of Environment, Lands and Parks, Victoria, Wildlife Bulletin B-67. 28 pp.

Hamilton, A.N., D.C. Heard, and M.A. Austin. 2004. British Columbia grizzly bear (Ursus arctos) Population estimate 2004. British Columbia Ministry of Water, Land, and Air Protection, Biodiversity Branch. Victoria, B.C. 7 pp.

Hosmer, D.W., Jr. and S. Lemshaw. 1989. Applied Logisitic Regression. John Wiley & Sons, New York, New York, USA.

Hovey, F.W. and B.N. McLellan. 1996. Estimating population growth of grizzly bears from the Flathead River drainage using computer simulations of reproductive and survival rates. Canadian Journal of Zoology. 74:1409-1419.

Garshelis, D. L., M. L. Gibeau, and S. Herrero. 2004. Grizzly bear demographics in and around Banff National Park and Kananaskis Country, Alberta. Journal of Wildlife Management 69:277-297.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kasworm, W.F. and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8;79-84.

Kasworm, W.F., H. Carriles, and T.G. Radandt. 2006. Cabinet-Yaak grizzly bear recovery area 1999 research and monitoring progress report. United States Fish and Wildlife Service. Grizzly Bear Recovery Coordinator's Office. Missoula, Montana.

Knight R.R., and L.L Eberhardt 1985. Population dynamics of Yellowstone grizzly bears. Ecology 66:323-334.

Liu, C., Berry, P.M., Dawson, T.P., Pearson, R.G., 2005. Selecting thresholds of occurrence in the prediction of species distributions. Ecography 28, 385–393.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuring. 1996. Relationships among grizzly bears, roads, and habitat use in the Swan Mountains, Montana. Journal of Applied ecology. 33:1395-1404.

Mace, R.D. and J.S. Waller. 1998. Demography and population trend of grizzly bears in the Swan Mountains, Montana. Conservation Biology. 12:1005-1016.

Mace, R.D., J.S. Waller, T.L. Manley, K. Ake, and W.T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in Western Montana. Conservation Biology 13:367-377.

Manly, B.F.J., L.L. McDonald, D.L. Thomas. T.L. McDonald, and W.P. Erickson. 2002. Resource Selection by Animals. Kluwer Academic Publishers. Boston. 221 pp.

Mattson, D.J., R.R. Knight, and B. Blanchard. 1987. The effects of development and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management. 7:259-274.

McGarigal K. S. Cushman,a nd S. Stafford. 2000 Multivariate Statistic for Wildlife and Ecology Research. Springer. New York. 283 pp.

McLellan, B.N. 1989. Dynamics of a grizzly bear population during a period of industrial resource extraction. I. Density and age-sex composition. Canadian Journal of Zoology. 67:1856-1860.

McLellan, B.N. 1998. Maintaining viability of brown bears along the southern fringe of their distribution. Ursus. 10:607-611.

McLellan, B.N. and D.M. Shackleton. 1988. Grizzly bears and resource extraction industries: effects of roads on behavior, habitat use, and demography. Journal of Applied Ecology. 35:451-460.

McLellan, B.N., F. Hovey, R.D. Mace, J.G. Woods, D.W. Carney, M.L. Gibeau, W.L. Wakkinen, and W.F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management. 63:911-920.

Mowat, G. and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management. 64:183-193.

Mowat, G., DC. Heard, and T. Gaines. 2004. Predicting grizzly bear (*Ursus arctos*) densities in Britiesh Columbia using regression model. British Columbia Ministry of Environment. Victoria, BC. 16 pp.

Nams, V.O, G. Mowat, and M.A. Panian. 2005. Scale dependent habitat selection by grizzly bears. Biological Conservation 128:109-119.

Nielsen, S.E., M.S. Boyce, G.B. Stenhouse, and R.H.M. Munro. 2002. Modeling grizzly bear habitats in the Yellowhead ecosystem of Alberta: taking autocorrelation seriously. Ursus:13:45-56.

Nielsen, S.E., S. Herroro, M.S. Boyce, R.D. Mace, B. Benn, M Gibeau, and S. Jevons. 2004a. Modeling the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies Ecosystem of Canada. Biological Conservation 120:101-113.

Nielsen, S.E., M.S. Boyce, and G.B. Stenhouse. 2004b. Grizzly bears and forestry I: selection of clearcuts by grizzly bears in west-central Alberta. Forest Ecology and Management 199:67-82.

Nielsen, S. E., G. B. Stenhouse, and M. S. Boyce. 2006. A habitat-based framework for grizzly bear conservation in Alberta. Biological. Conservation. 130:217–229.

Paetkau, D. 2003. An empirical exploration of data quality in DNA-based population inventories. Molecular Ecology. 12:1375-1387.

Peek, J., J. Beecham, D. Garshelis, F. Messier, S. Miller, and D. Strickland. 2003. Management of grizzly bears in British Columbia: a review by an independent scientific panel. BC Ministry of Water. Lands, and Air Protection. Victoria. 90 pp.

Proctor, M.F. 2003. Genetic analysis of movement, dispersal and population fragmentation of grizzly bears in southwestern Canada. PhD Thesis. University of Calgary. 147 pp.

Proctor, M., B.N. McLellan, C. Strobeck, and R. Barclay. 2005a. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of the Royal Society, London. 272:2409-2416.

Proctor, M.F., C. Servheen, W. Kasworm, and W. Wakkinen. 2005b. South Purcell-Yaak and south Selkirk ecosystem grizzly bear mortality summary. BC Ministry of Environment, Nelson BC. 19 pp.

Proctor, M., J. Boulanger, S. Nielson, W. Kasworm, C. Servheen and T. Radandt. 2007a Abundance and density of Central Purcell, South Purcell and Yahk Grizzly Bear Population Units in southeast British Columbia**.** BC Ministry of Environment. Nelson BC.

Proctor, M., B. McLellan, J. Boulanger, C. Apps. G. Mowat, D. Paetkau, and G. Stenhouse. 2007b. Ecological investigation of Canadian grizzly bears using hair-snagged DNA, 1995-2005. Ursus. Submitted.

Pyare, S., S. Cain, D. Moody, C. Schwartz, and J. Berger. 2004. Carnivore re-colonization: reality, possibility and a non-equilibrium century for grizzly bears in the Southern Yellowstone Ecosystem. Animal Conservation. 7:1-7.

Schwartz, C.C., M.A Haroldson, G.C. White, R.B. Harris, S. Cherry, K.A. Keating, D. Moody, and C. Servheen. 2005. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 161.

Servheen, C., M. Haroldson, K. Gunther, K. Barber, M. Brucino, M. Cherry, B. DeBolt, K. Frey, L. Hanauska-Brown, G. Losinski, C. Schwartz, and B. Summerfield. 2004. Yellowstone mortality and conflicts reduction report. Presented to the Yellowstone Ecosystem Subcommittee April 7, 2004.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry, 3rd Edition. W.H. Freeman and Company. New York. 887 pp.

Strom, K.B., M. Proctor, and J. Boulanger. 1999. Grizzly bear population survey in the central Purcell Mountains, British Columbia. B.C. Environmental Assessment Office. Victoria, B.C. Canada. 59 pp.

Wakkinen, W.L., and W.F. Kasworm. 1997. Grizzly bear and road density relationships in the Selkirk and Cabinet–Yaak recovery zones. U.S. Fish and Wildlife Service, Missoula, Montana, USA.

Wakkinen, W.L., and W.F. Kasworm. 2004. Demographic and population trends of grizzly bears in the Cabinet–Yaak and Selkirk ecosystems of British Columbia, Idaho, Montana, and Washington. Ursus 15 Workshop Supplement: 65–75.

White, G. C. 1996. NOREMARK: Population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50-52.

White, G.C., and K.P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study Supplement 46:120-138.

Woods, J.G., B.N. McLellan, D. Paetkau, M. Proctor, D. Lewis, and C. Strobeck. 1999. Genetic tagging free-ranging black and brown bears. Wildlife. Society Bulletin 27:616-627.