FINAL REPORT

CARIBOO REGION BADGER PROJECT: YEAR END REPORT 2006-07

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EXECUTIVE SUMMARY

The Cariboo Region Badger Project was initiated in 2003 to determine the distribution and abundance of badgers at the northern periphery of their range to support recovery activity for the species. To date, we have identified 736 burrow locations and recorded 101 observations of animals reported by the public. In 2006, we collected 188 shed and snagged hair samples from 67 burrow locations and 4 tissue samples from road killed badgers. We assigned 108 samples to individual badgers using DNA fingerprinting. We have identified a total of 51 badgers (23 females, 28 males) in the Cariboo region, including 2 litters (5 kits in 2005, and 4 kits in 2006). The estimated badger population (Jolly-Seber model) in the study area was 24.5 badgers (95% CI = 18.3 – 34.1) in 2004, and 32.3 badgers (95% CI = 26.6 – 44.5) in 2005. The minimum number of badgers alive in the population in 2006 is 26. We estimated areas used by individual badgers to be as small as 0.3 km^2 and as large as 1280 km^2. Nine badgers have died since 2003, and at least 8 of these were confirmed roadkills.

Recovery activities to date include the proposal of 11 WHAs for designation under the Forest and Range Practices Act, treatment of WHAs and First Nations reserve lands to reduce forest encroachment/ingrowth, development of best management practices to maintain/improve habitat, and posting 5 badger road crossing signs on Highway 97 to warn motorists of high potential roadkill areas. Research in 2007 will focus on the hazards of roads for badgers with financial support from the B.C. Ministry of Transportation and the B.C. Conservations Corps.

ACKNOWLEDGEMENTS

The Cariboo Region Badger Project was initiated and coordinated by Roger Packham, Ministry of Environment, 100 Mile House, British Columbia. The project was funded by the Habitat Conservation Trust Fund (HCTF), Habitat Stewardship Program (HSP), and the BC Conservation Corps (BCCC), BC Ministry of Environment (MoE), and BC Ministry of Forests and Range (MoFR). Funding for helicopter survey flights was provided by the BC Ministry of Water, Land and Air Protection (MWLAP, now Ministry of Environment) and Ministry of Forests (MoF, now Ministry of Forests and Range). Field work was conducted by Roger Packham, Corinna Hoodicoff, Gerry Dileva, Philippe Verkerk, Michael Janzen and Julie Steciw. DNA was analyses were completed by Wildlife Genetics International (Nelson, BC), and Dr. David Paetkau assisted with interpretation of data. Bill Chapman (MoFR) provided advice and conducted assessments of soils used by badgers, and Bill Harrower assisted with some statistical analysis. The Canoe Creek Indian Band (CCIB) Inventory Team was coordinated by Scott Cousins, Natural Resource Coordinator, and included Mildred Kalelest, Melvin Louis, Fred Louis, Kevin Harry and Allison Harry. Their efforts were funded by the CCIB and the Interdepartmental Recovery Fund. Thanks are extended to the public for reporting badger sightings and to private landowners and Crown grazing licencees for maintaining badger habitat. Eric Lofroth (MoE) and Trevor Kinley (Sylvan Consulting) provided valuable comments on earlier versions of the report.

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The *jeffersonii* subspecies of North American badger (*Taxidea taxus*) is considered endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Newhouse and Kinley 1999). Recent estimates suggest there are less than 400 badgers remaining in British Columbia. Until recently, badgers were thought to be at low densities in the Cariboo region because it is the northern periphery of their range (Figure 1.1). Surveys in 2003, however, indicated that there were more badgers in the Cariboo region than originally believed and this observation helped initiate the Cariboo Region Badger Project.

Through the Cariboo Region Badger Project, the Ministry of Environment (MoE) has been raising awareness of badgers in the region, soliciting reports of badgers and their burrows from the public, and conducting an inventory of badgers. The study area includes portions of the Cariboo Basin, Fraser River Basin, Cariboo Plateau and Tranquille Upland Ecosections (Demarchi 1996) (Figure 1.2). Inventory methods for badgers developed during this project involve remotely collecting hair from badgers and using DNA fingerprinting to identify individuals. We estimated areas used by individuals and identified movements, evaluated sex ratio and minimum age, and estimated survival rates for of badgers in the study area. The Cariboo Region Badger Project has resulted in the development of provincial inventory standards for badgers (RISC 2007), contributed to a better understanding of badger ecology and abundance, proposed the establishment of Wildlife Habitat Areas (WHAs) around burrow concentrations and key habitats, and has resulted in a number of other conservation initiatives and research projects.

The following report summarizes the activities and results from research conducted in 2006-07 and discusses previous years (2003-05) results. For more detailed results from 2003-05 see the Summary Report 2003-2005 (Packham and Hoodicoff 2006).

Source: Adams and Kinley 2004

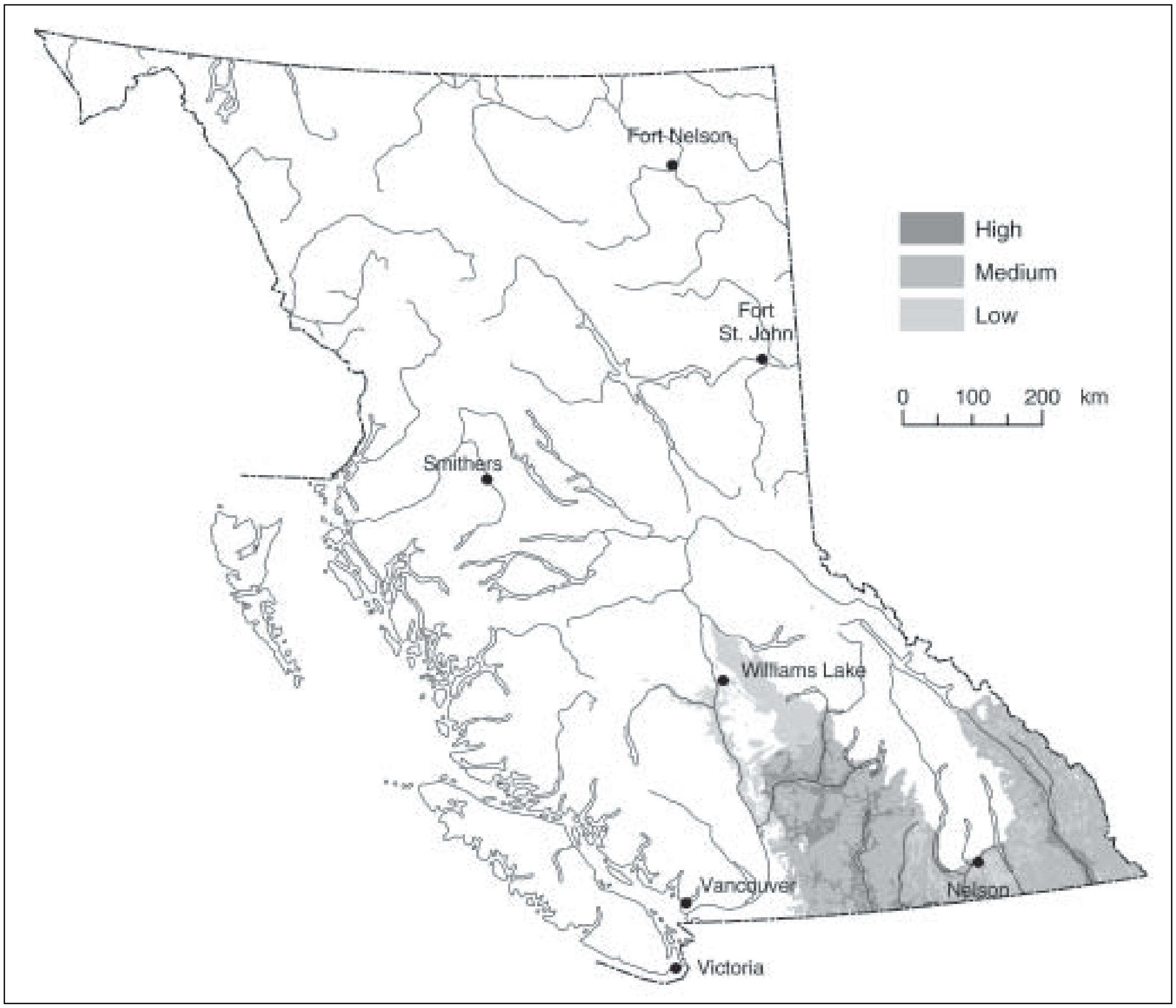

Figure 1.1. Potential habitat of *jeffersonii* badgers in British Columbia.

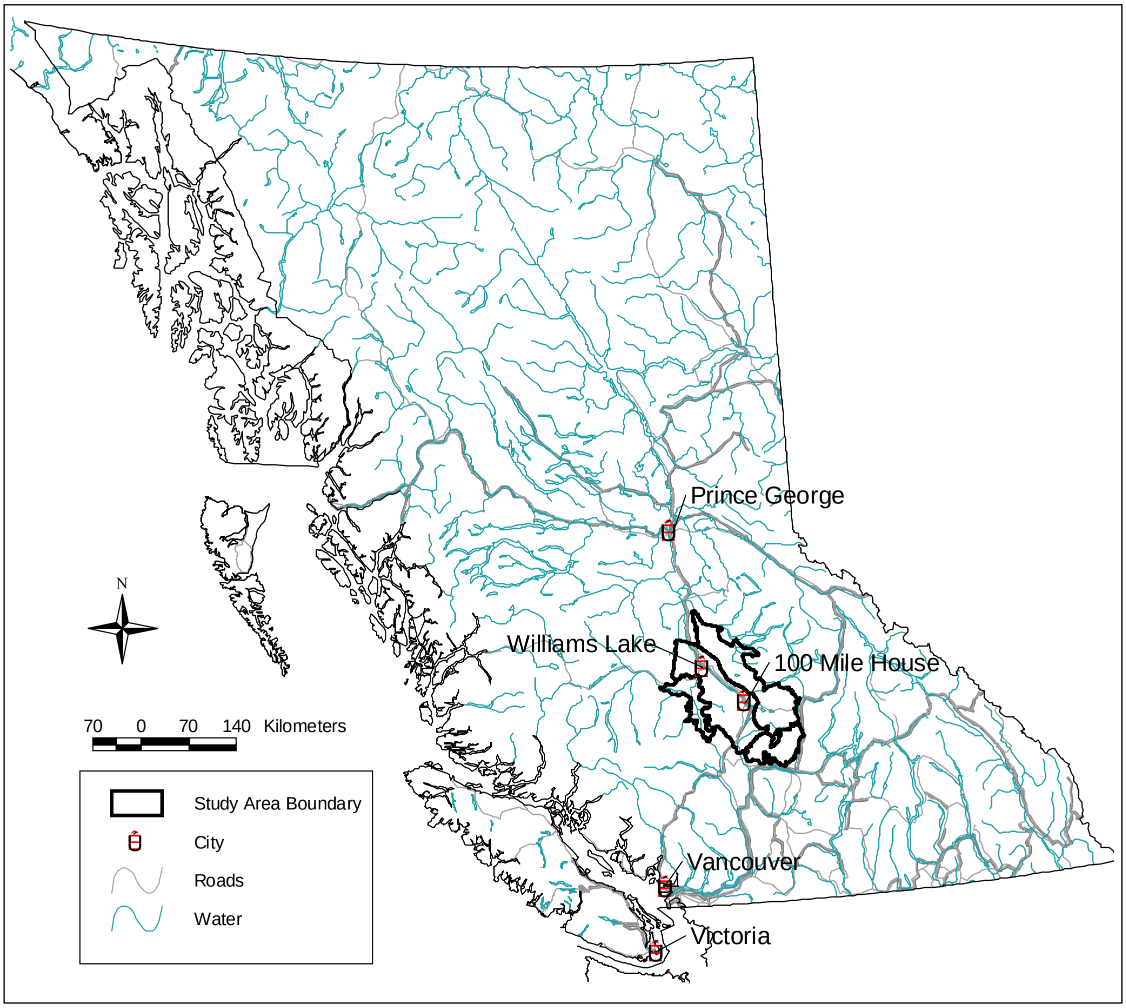

Figure 1.2. Cariboo Region Badger Project study area.

1.2 PROJECT OBJECTIVES

The general objectives for the Cariboo Region Badger Project are to determine distribution and abundance of badgers, and to collect ecological information to support recovery activities in the region. Specific objectives for the project are to:

1. Raise local awareness of badgers and their habitats in the Cariboo region;
2. Locate burrows and describe badger habitat in the Cariboo region;
3. Remotely monitor the population by using genetic fingerprinting to estimate population size; and,
4. Estimate size of area used and movements by individual badgers identified in the region.

2.0 METHODS

2.1 LOCAL AWARENESS OF BADGERS

The Cariboo Region Badger Project used a community awareness campaign to improve awareness of badgers and their habitat in the Cariboo region, and to solicit sightings of badgers and their burrows from the public. We informed the public of our research by hanging posters throughout the study area to solicit sightings via a 'badger reporting line.' Information pamphlets were delivered during landowner visits and newspaper articles were published in local papers. Follow-up site visits were conducted where badger sightings were reported or where researchers suspected badger habitat or activity.

2.2 BADGER OBSERVATIONS, BURROW LOCATIONS AND MORTALITIES

To determine the extent of badger distribution, we conducted aerial and ground surveys of grassland habitats within the study area for badger burrows. An initial helicopter flight was conducted in January 2003, followed by two flights in March 2004. We surveyed the area from Clinton to the west side of Fraser River as far north as Beaumont Creek, and along the Chilcotin River by helicopter. On March 31, 2006, we conducted a helicopter search along the Fraser River.

Additional burrows were located while driving local roads or were reported by the public. We drove paved highway and gravel roads from Loon Lake in the south to Williams Lake in the north, and from Bonaparte River in the east to the Gang Ranch and Fraser River in the west. All reports of possible badger burrows or sightings were followed by ground reconnaissance. We recorded the UTM coordinates of all burrows and badger sightings reported, and created a database of badger occurrences and burrows in the Cariboo region.

Badger mortalities in the Cariboo were mainly attributed to roadkill. Roadkill badgers were usually reported by the public or the highways maintenance contractor, Interior Roads Limited. Once roadkill badgers were retrieved, DNA samples were taken to determine identity and depending on the condition of the animal, body measurements were taken.

2.3 HAIR COLLECTION AND DNA FINGERPRINTING

2.3.1 Hair Collection

We collected hair from badgers to genetically identify individuals using DNA fingerprinting (Taberlet and Luikart 1999). This method has been used to inventory bears (Woods et al. 1999; Mowat and Strobeck 2000; Poole et al. 2001), and has been successful with other species, such as American marten, European badgers and wolves (Mowat and Paetkau 2002; Frantz et al. 2004; Creel et al. 2003). Badgers are a likely candidate for this method because hair can be collected at burrows that are repeatedly used by individuals. Once sufficient samples are collected, genetic material can provide information on the relatedness of individuals, and genetic structure of a population (Piggott and Taylor 2003).

We opportunistically collected hair shed at burrows and systematically collected hair snagged from badgers using four different techniques that evolved over the course of the project:

1) Barbed Wire Snag: In 2003, barbed wire was looped into a semi-circle and the ends secured inside of the burrow entrance (Appendix A, Photo 1). The ends of the barbs were clipped to avoid harming any animals.

2) Velcro Snag: In 2004, we used Velcro to improve hair collection and eliminate the possibility of badger injury from barbed wire. Velcro snags were made from 30 cm of 2 cm wide metal strapping (used for wrapping lumber) formed into a 'D' (Appendix A, Photo 2). Two 7.5 cm nails were inserted through holes drilled at the base of the 'D' and were used to secure the snag inside the burrow. Three rivets were placed at each edge and middle to secure the strapping in its shape. The 'hook' side of adhesive Velcro (2 cm wide) was placed along the arc to capture hair.

3) Pinned Knaplock Snag: In 2005, we remodeled the Velcro snags to improve their effectiveness, particularly later in summer after winter coats were shed. Two squares (approximately 2 cm by 2 cm) of pinned knaplock (carpet edging) were riveted to the curved edge of the same metal strapping set used in 2004 (Appendix A, Photo 3). A rubber mallet was used to bend the teeth of the knaplock down to prevent injury to any animal. Lengths of wire attached to the metal strapping were forced through the soil to the surface and fastened to further anchor the snags at the burrow. This method was used again in 2006.

4) Perimeter Snag: In 2005 and 2006, we used a larger snagging device around the perimeter of a number of burrows where multiple badgers were observed (e.g., a family group). Lengths of 1"x2" lumber with pinned knaplock secured to the undersides were erected approximately 30 cm off of the ground surface around all of the burrow openings (Appendix A, Photos 4 and 5). Again, the teeth of the knaplock were bent down to prevent injury to any animal.

Badger hair snags were set opportunistically at burrow entrances that had evidence of recent use, e.g., freshly excavated soil, tracks, or an animal observed. Hair snags were placed inside each burrow, along the roof of the entrance, where an animal entering or exiting would brush against them and deposit hair. Snags were placed far enough inside of the burrow to avoid contact with precipitation, and were handled with leather gloves to minimize human scent.

Snags were checked approximately every 4 to 6 days for hair. Some sets in remote locations were checked less often. All of the hair was collected from each snag and placed inside a paper envelope and stored at room temperature. At the end of the field season, all samples were sent to Wildlife Genetics International lab for DNA fingerprinting.

2.3.2 Genetic Analyses

Hair samples were extracted using QIAGEN's DNeasy Tissue kits following the manufacturer's instructions[1]. Whenever possible, ten guard hair roots were used. In some cases, however, whole clumps of under-fur were extracted rather than clipping individual roots. The remaining portion of samples were archived and stored under appropriate laboratory conditions.

We selected markers (microsatellite loci) to assign hair samples to individual badgers based on results from Davis and Strobeck (1998) and Kyle et al. (2004). Six markers (*Ma-1, Tt-1, Tt-2, Tt-3, Tt-4, Mvis072*) successfully used in previous years were used to assign hair samples to individuals (Paetkau 2007). All samples were pre-screened with 1 marker to test for viability of genetic material. Samples that did not perform well in pre-screening were either not badger hairs or were of poor quality and were discarded. Remaining samples were screened with the other 5 markers to assign samples to individuals. Gender of each individual was determined using the ZFX/ZFY/SRY gender test.

We excluded samples that did not produce definitive results for more than 3 loci from further analyses. Removing low quality samples reduced the probability of genotyping error. Inconsistent genotyping of different samples from the same individual will create pairs of geonotypes that are highly similar, leading to overestimation of the number of individuals sampled. To ensure that samples were not mistakenly assigned to individuals, we subjected them to computerized comparison of all pairs of unique genotypes (i.e. mismatched pairs) (Paetkau 2003).

[1] http://www.qiagen.com/

We explored using 12 unpublished markers developed for California fishers (*Martes pennanti*) (Mark Jordan pers. comm.) as possible new markers for Cariboo badgers. We tested these on 7 badgers, and 2 markers (*MP0182* and *MP0120*) were variable enough to be of use. We applied these to 1 sample from each badger to test if they could improve analysis of individual identity. We compared the distribution of mismatched pairs, including the additional 2 markers to the distribution of the original 6 markers to identify whether the number of similar genotypes was reduced. We also error checked samples checked using a computerized comparison of all pairs of unique genotypes to detect those that were highly similar and may have been indicative of genotyping error.

We assessed viability (number of samples successfully assigned to an individual) of hair samples using a Pearson's chi-squared test with Yates' continuity correction.

2.4 POPULATION ESTIMATION

We used the minimum number of badgers detected with DNA fingerprinting as our approximation of the minimum population of badgers in the study area. We used mark-recapture models (program MARK; White 2000), and calculated badger abundance using Jolly-Seber methods (Krebs 1989). Population estimates were calculated using all samples that were assigned to individuals since 2003, and were not filtered for temporal or spatial independence.

Equal catchability may vary with behaviour of individuals near hair snags, and unequal detection opportunity may exist because of where hair snag were located. Because snags were set in burrows that were likely used repeatedly by some individuals, and not randomly, we expect the equal catchability assumption to be violated. We tested for this using the Leslie, Chitty and Chitty approach (Leslie et al. 1953 as described in Krebs 1989), where the estimated the number of new additions to the marked population are compared to the observed value. In this test we considered marked animals as those individuals caught at least twice, and unmarked animals as those caught only once (Krebs 1989).

2.5 DISTRIBUTION OF ANIMAL DETECTIONS AND MOVEMENTS

We calculated the 100% MCP polygons (Mohr 1947) for each individual detected since 2003 using ArcView GIS (ESRI 1998). We calculated the distance between burrows used by an individual for badgers with at least two locations confirmed by DNA fingerprinting. We calculated distances moved by kits as that from the maternal burrow (e.g. B485) where each kit was first located in 2005, to the farthest burrow where each was located. We compared the differences between long-distance movements made by male and female badgers with t-tests calculated using SYSTAT software (SPSS Inc. 1998).

3.0 RESULTS

3.1 LOCAL AWARENESS OF BADGERS

There were 14 confirmed sightings of badgers reported to the 'badger reporting line' in 2006, for a total of 85 animal sightings reported since the project began in 2003. In addition to distributing information posters, one article was published in the 100 Mile House Free Press newspaper (Appendix B). Roger Packham also made a number of presentations on badger ecology to local schools and club meetings, including:

- BC Trappers Association in 100 Mile House (about 100 people) on March 18, 2006;
- Green Lake and Area Rate Payers Association Annual General Meeting (AGM) (about 70 people) on August 19, 2006;
- 108 Mile Community Association AGM (about 60 people) on November 15, 2006; and,
- 100 Mile Elementary School for grades 6 and 7 classes (about 50 students) on December 20, 2006.

In 2005, the Marmot Ridge Golf Course in 100 Mile House had a resident badger that hunted marmots both on and near the golf fairways. The golf course was positive to the benefits of badgers and their role in rodent control, and allowed a sign to be posted on their property to raise awareness of the badger.

Other landowners and grazing licencees in the study area continued to cooperate with our research efforts by reporting sightings of badgers and their burrows, and by supporting a grassland habitat rehabilitation program. The Canoe Creek Indian Band conducted an inventory of badger burrows (2004, 2005) in conjunction with the Cariboo Region Badger Project.

The Cariboo Region Badger Project reports have been posted on the *jeffersonii* Badger Recovery Team website (www.badgers.bc.ca).

3.2 BADGER OBSERVATIONS AND BURROW LOCATIONS

Prior to June 2003, we had observations of 16 badgers and 3 burrows in the Cariboo region[2]. Since this time, a total of 632 burrowing sites (locations where one or more burrows were observed) and 85 observations of animals have been documented (Table 3.1). Locations of burrows and sightings ranged from the town of Clinton in the south to north of Williams Lake, and from west of the Fraser River to the Bonaparte Plateau in the east (Appendix C). In 2006, we identified new areas of badger activity in the Sheridan Lake area and in extensive hay fields on private lands north of 100 Mile House (Appendix C).

Badger sightings and burrow locations were identified in 7 ecosections. Four of these (Cariboo Basin, Fraser River Basin, Cariboo Plateau and Tranquille Upland) are within the current study area and 3 are adjacent ecosections (Quesnel Highland, Pavilion Ranges and Thompson Basin) (Table 3.2). Of the total 746 burrows and badger sightings, 69% were in the Interior-Douglas Fir biogeoclimatic zone (IDFdk3 and IDFxm subzones; Steen and Coupe 1997), 18% were in the Bunchgrass biogeoclimatic zone (BGxh3 and BGxw2 subzones), and 12% were in the Sub-boreal Pine Spruce biogeoclimatic zone (SBPSmk subzone).

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[2] Collected by Artemis Wildlife Consultants, Armstrong, BC

Table 3.1. Burrows, badger sightings and badger mortalities recorded during the Cariboo Region Badger Project.

	Prior to 2004	2004	2005	2006	Total
Burrows	327	138	103	67	635
Sightings	49	9	30	13	101
Mortalities	2	1	2	5	10
Total	378	148	135	85	746

Table 3.2. Ecosections (Demarchi 1996) where burrows and badger sightings were recorded.

Ecosection (Ecosection Area) and Biogeoclimatic Subzone*	Number of Locations (*n*)	% Total of Study Area and % Burrows per Zone
Cariboo Basin (9,136 km^2)	**496**	**66.5%**
IDFdk3	466	94.0%
IDFxm	20	4.0%
IDFxw	10	2.0%
Fraser River Basin (2,327 km^2)	**142**	**19.0%**
BGxh3	51	35.9%
BGxw2	80	56.3%
IDFdk3	1	0.7%
IDFdk4	2	1.4%
IDFxm	8	5.6%
Cariboo Plateau (8,143 km^2)	**95**	**12.7%**
SBPSmk	89	93.7%
SBSdw1	5	5.3%
SBSdw2	1	1.1%
Tranquille Upland (2,960 km^2)	**8**	**1.1%**
IDFdk3	7	87.5%
MSxk	1	12.5%
Pavilion Ranges (9,136 km^2)	**1**	**0.1%**
IDFdk3	1	100.0%
Quesnel Highland (7,618 km^2)	**3**	**0.4%**
ICHmk3	1	33.3%
IDFmw2	2	66.7%
Thompson Basin (3,096 km^2)	**1**	**0.1%**
PPxh2	1	100.0%
Total	**746**	

* Steen and Coupe 1997

3.3 HAIR COLLECTION AND IDENTIFICATION OF INDIVIDUAL BADGERS

3.3.1 Hair Collection

We set a total of 224 snags at 82 burrow sites between May 2 and September 19 (Table 3.3), and collected an additional 65 shed hair samples at 43 burrow sites. As in 2005, we focused additional effort on collecting hair samples from a maternal burrow (B549) where three badgers were observed on May 19, 2006. Three pinned knaplock snags were set at burrow entrances (June 14-16) and a perimeter snag was set (June 17-22) around the site (Table 3.4). We gathered 37 snagged hair samples and 10 shed hair samples from this site.

We sent 192 samples to the lab for DNA fingerprinting, including tissues samples colleted from four badger carcasses recovered in 2006 (Table 3.5; Appendix D). Data from 2003 to 2006 are presented in the following tables for comparison.

Table 3.3. Summary of hair snagging effort between 2003 and 2006.

	2003	2004	2005	2006
Snag Method	Barbed Wire	Velcro	Pinned Knaplock[2]	Pinned Knaplock[2]
# Snags Set	104	264	303	224
Trapping Session (days)	98	102	124	140
Snag Effort (trap·days)[1]	1,551	1,860	8,327	7,304
# Locations Snagged	68	109	102	82

[1] Snag effort is measured in trap·days (1 trap set for 24 hours)
[2] These figures do not include activities at maternal burrows (B485 in 2005 and B549 in 2006). See Table 3.4.

Table 3.4. Summary of hair snagging effort at maternal burrows in 2005 and 2006.

	2005 at B485	2006 at B549
# Snags Set and Method	6 Pinned Knaplock 1 Perimeter	3 Pinned Knaplock 1 Perimeter
Trapping Session (days)	49	7
Snag Effort (trap·days)[1]	59	17

Table 3.5. Number of hair and tissue samples collected for DNA fingerprinting from 2003 to 2006.

Sample Type	2003	2004	2005	2006	Total
Shed Hair	49	98	38	65	250
Snagged Hair (Burrow)	50	69	109	91	319
Snagged Hair (Perimeter)	–	–	25	32	57
Tissue from Carcasses	2	1	2	4	9
Total Samples	101	168	174	192	635
# Locations Sampled	66	104	70	67	217

3.3.2 DNA Sample Viability

Of 192 total samples analyzed in 2006, 9 (5%) lacked suitable material for extraction and 75 (39%) produced insufficient data to establish individual identity (Paetkau 2007). The remaining 108 (56%) samples were successfully assigned to 30 individuals, 14 of which were previously undetected. Hair and tissue samples assigned to individual badgers and associated viability of samples (% samples assigned of total collected) since 2003 are presented in Table 3.6.

Snagged hair samples collected using all methods were assigned to individuals 49% of the time, which was more frequent than assignment of shed hair samples (32%) (G = 7.30, df = 1, p = 0.007). Hair samples from pinned knaplock snags, including perimeter sets, were assigned to individuals 71% of the time compared to 36% assignment rates from samples collected with other snagging methods, i.e. Velcro and barbed wire (G = 11.86, df = 1, p <0.001).

Table 3.6. Number of hair and tissue samples assigned to individual badgers and percent samples assigned of total collected.

	2003		2004		2005		2006		Total	
Sample Type	#Samples Assigned	%Total Collected	#Samples Assigned	%Total Collected	#Samples Assigned	%Total Collected	#Samples Assigned	%Total Collected	#Samples Assigned	%Total Collected
Shed Hair	11	22%	19	19%	25	66%	26	40%	81	32%
Snagged Hair (Burrow)	26	52%	17	25%	83	76%	59	65%	185	58%
Snagged Hair (Perimeter)	–	–	–	–	21	84%	19	59%	40	70%
Tissue from Carcasses	2	100%	1	100%	2	100%	4	100%	9	100%
Total	39	39%	37	22%	131	88%	108	56%	315	54%

3.3.3 Error Checking and Markers

All DNA samples collected from 2003-2006 error-checked for possible genotyping errors. Reanalysis uncovered scoring errors which resulted in the re-assignment of 17 samples to badger F135.

Four pairs of genotypes were matched at 5 of 6 markers (1MM-pair) using the original 6 markers. Inclusion of marker *MP0120* resulted in only a single 1MM-pair. Inclusion of marker *MP0182* resulted in no 1MM-pairs and only 2 2MM-pairs. Based on marker variability (Table 3.7), marker *MP0182* did more to lower the inferred match probability than marker *MP0120* (Paetkau 2007). Since no 1MM-pairs were detected using this 8-marker system, it is unlikely that different animals may have been assigned the same multilocus genotype, and thus very unlikely that the number of individuals identified were overestimated by inconsistent genotyping.

Table 3.7. Measures of marker variability in Cariboo badger samples based on 51 individuals recognized at the end of 2006. H_E is expected heterozygosity, H_O is observed heterozygosity and A is observed number of alleles (from Paetkau 2007).

Locus	***N***	H_E	H_O	**A**
Ma1	51	0.61	0.61	4
Tt1	51	0.74	0.76	4
Tt4	51	0.73	0.73	7
Tt2	51	0.65	0.73	4
Tt3	50	0.73	0.70	5
Mv72	51	0.66	0.71	4
MP0182	50	0.69	0.72	5
MP0120	51	0.59	0.57	6
Mean		0.67	0.69	4.9

3.4 POPULATION ESTIMATION

3.4.1 Individuals

In 2006, 30 individuals were identified 108 times using DNA fingerprinting from all samples collected (i.e. shed hair, snagged hair and tissue). Since 2003, 51 badgers (23 females, 28 males) have been identified in the Cariboo region a total of 315 times (Table 3.8). Five male badgers (M004, M031, M035, M049 and M097) first identified in 2003 were still alive in 2006, and are now confirmed to be at least 3 years old.

Table 3.8. Summary of badgers identified in the Cariboo region between 2003 and 2006.

Sex	Individual	Number of Times Detected with DNA fingerprinting				
		Prior to 2004	2004	2005	2006	Total
M	002	1 (*mortality*)				1
M	004	2	3	3	1	9
M	005	2	1	9	–	12
M	008	7	3	–	–	10
M	009	2	1	8	–	11
M	031	2	8	12	9	31
M	035	2	–	2	7	11
M	036	6	2	–	–	8
F	042	1	–	1	–	2
M	049	3	5	11	7	26
F	065	3	1 (*mortality*)			4
M	097	6	–	2	3 (*mortality*)	11
F	104	1	1	–	–	2
F	126		4	1	1	6
F	127		1	–	17	18
F	135		1	–	–	1
F	161		1	1	–	2
M	164		1	–	–	1
F	179		2	13	–	15
F	249		1	–	–	1
F	259	1 (*mortality*)				1
F	271		1	–	2	3
M	278			5	–	5
M	279			8	1 (*mortality*)	9
F	280			7 (*mortality*)		7
M	286			7 (*mortality*)		7
F	312			2	–	2
F	316			10	1	11
M	326			8	3	11
F	328			9	–	9
M	355			1	1	2
F	366			2	–	2
M	367			1	–	1
M	383			1	2	3
M	394			1	11	12
M	409			5	4	9
M	442			1	2	3
M	490				1	1
M	493				1	1

Table 3.8. Continued.

Sex	Individual	Number of Times Detected with DNA fingerprinting				
		Prior to 2003	2004	2005	2006	Total
F	507				4	4
M	513				9	9
M	520				2	2
F	533				5	5
F	534				4	4
F	537				1 (*mortality*)	1
F	544				1	1
M	552				3	3
F	581				1	1
M	592				2	2
F	613				1 (*mortality*)	1
M	617				1	1
Total Detections		39	37	131	108	315
Total Individuals		12	17	26	30	51

3.4.2 Population Estimate

The total population detected and the minimum number of badgers alive has increased since 2003 (Figure 3.1). The minimum number of badgers alive in 2006 was 26. The Jolly-Seber population estimate for 2004 was 24.5 (95% CI = 18.3 – 34.1), and for 2005 was 32.3 (95% CI = 26.6 – 44.5) (Table 3.9). None of the models used in program MARK provided an estimate of population size because numerical convergence was not reached (Cooch and White 2006). The test of equal catchability indicated that the population was overestimated by 10% (Z'_{est} =22.08, Z'_{obs} = 20.00) as a result of violating this assumption.

We detected a maximum of 42 badgers living within a 6,512 km^2 area, estimated from the minimum convex polygon area surrounding the maximum number of badgers. At least 17 badgers were identified in about 11 km^2 (one badger per 0.6 km^2) in the Alberta and River Lakes area since 2003. Four to 5 badgers were detected at 3 different burrows (B069, B226, B355) in the area. Since 2003, at least 5 badgers have been identified at the Marmot Ridge Golf Course at 100 Mile House (F179, M279, M355, M617 and F280). Other burrows used by at least 4 badgers were found on the North Bonaparte Road (B195), at the Green Lake Gravel Pit (B191), and at the 2 maternal burrows (B485 and B549).

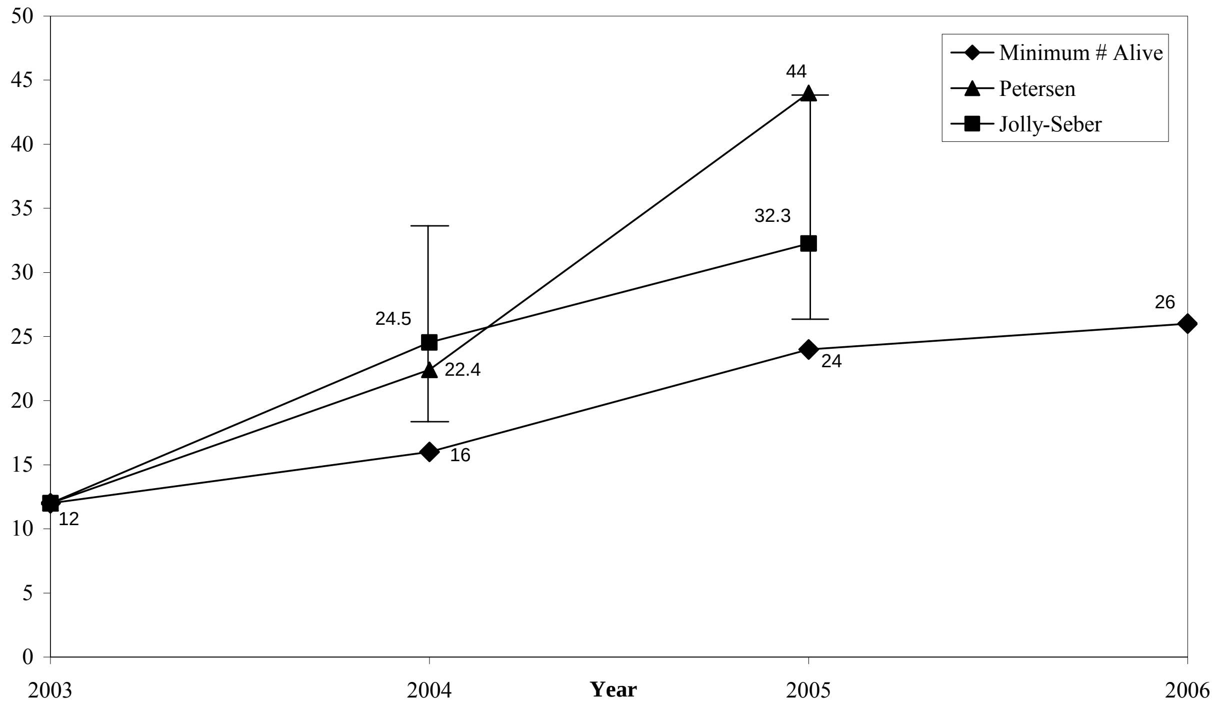

Figure 3.1. Estimated population size of badgers in the Cariboo (minimum number alive) and Jolly-Seber estimate (95% CI).

Table 3.9. Population metrics for Cariboo badgers (Jolly-Seber technique).

	2003	2004	2005	2006
Proportion of population marked (α)	0.000	0.556	0.444	0.548
Size of marked population (M)	0.0	13.6	14.3	–
Population estimate (N) 95% Confidence Interval	–	24.5 (18.3-34.1)	32.3 (26.6-44.5)	–
Probability of survival (φ)	–	0.695	–	–
Number joining population (B)	–	15.896	–	–
New to marked population (Z')	–	22.886	19.593	–

3.4.3 Family Groups

In 2006, 5 individuals (3 females, 2 males) were identified from the samples collected at the maternal burrow at the northeast end of Horse Lake (B549). Results of the genetic analysis suggest that F507 is the mother of kits M513, M520, F533 and F534. The father of the litter appears to be M279, and based on his known genotype, he could also be the father of F507.

In 2005, female F179 had four kits (F316, M326, F328, and M355). Genetic analysis indicates the sire of this litter may also be M279. Three of the kits were detected again in 2006 (Appendix E). In May, female F316 was located 66.6 km northwest of the maternal burrow in an area where a male badger M286 was roadkilled in 2005. In August 2006, male M326 was located as far as 20.0 km and male M355 was located 19.3 km to the west and southwest of the maternal burrow, but near the home ranges of his mother and father. The mother, F179, and kit F328 were not detected this year.

3.4.4 Mortality

Nine badger deaths have been confirmed to date in the region. All but one is attributed to roadkill (Table 3.10; Appendix C). At least 4 badgers were killed by vehicles in 2006; 3 of these were killed on Highway 97 within 17 km of each other in July. The fourth badger, a kit of the year, was killed crossing Exeter Road just outside of 100 Mile House in September. Another unconfirmed roadkill was reported at 108 Mile on Highway 97 in October, but no carcass was recovered.

Table 3.10. Badgers mortalities confirmed in the Cariboo region between 2003 and 2006.

Sex	Individual	Year	Date	Location
F	259	2001	unknown	Roadkill on Meadow Lake Road (~5 km)
M	002	2002	December	Accidentally trapped near Green Lake
F	065	2004	4 November	Roadkill on Highway 24 near Fawn Creek Rd
M	286	2005	14 June	Roadkill on Highway 97 at 144 Mile
F	280	2005	13 December	Roadkill on Highway 97 at 101 Mile
M	279	2006	5 July	Roadkill on Highway 97 at 101 Mile
F	613	2006	10 July	Roadkill on Highway 97 at 112 Mile
M	097	2006	17 July	Roadkill on Highway 97 at 108 Mile
F	537	2006	28 September	Roadkill on Exeter Road

3.5 BADGER DISTRIBUTION AND MOVEMENTS

Distribution of confirmed locations (100% MCP outlines) were calculated for 20 badgers, all detected in fewer than 20 locations (Table 3.11, Appendix F). The smallest area was 0.3 km^2, calculated from three locations that form a very narrow triangle 4.9 km long. The largest was 1280 km^2 calculated for a badger M008.

The longest distance between two burrows used by an individual was calculated for 29 badgers (Table 3.11). The longest distance recorded was for female kit F316, who in 2006, was located 66.6 km away from her maternal burrow (B485) where she was first located in 2005. The average longest distance between burrows used by females was 19.0 km (n = 10, SD = 20.5), and by males was 26.4 km (n = 19, SD = 18.2). There was no significant difference between the sexes (t = 0.97, df = 16.6, P = 0.14).

Table 3.11. Area summary of distribution of Cariboo badger locations (100% MCP) and longest distances between DNA sampling locations (2003 - 2006).

Sex	Individual	Number of Locations	100% MCP (km^2)	Longest Distance Between Locations (km)
M	004	7	80.4	24.0
M	005	10	190.0	45.4
M	008	10	1280.0	64.6
M	009	8	69.3	22.6
M	031	19	65.4	61.5
M	035	8	62.6	26.6
M	036	7	30.6	9.3
M	049	16	243.4	31.0
F	065	4	98.6	37.8
M	097	6	95.5	37.3
F	104	2	–	21.0
F	126	4	23.1	14.5
F	161	2	–	3.3
F	179	4	0.9	18.7
F	271	3	0.3	4.9
M	278	2	–	0.1
M	279	6	146.7	35.6
F	280	6	37.4	20.4
M	286	4	27.2	43.1
F	316	2	–	66.6
M	326	3	26.6	20.0
M	355	2	–	19.3
F	366	2	–	0.9
M	383	2	–	18.2
M	394	10	65.3	22.7
M	409	7	27.8	9.0
M	442	2	–	4.9
F	507	2	–	1.4
M	552	3	1.3	7.1
	Mean (SD)	5.6 (4.3)	128.1 (278.5)	23.9 (18.8)

4.0 DISCUSSION

4.1 BADGER OBSERVATIONS AND BURROW LOCATIONS

In 2006-07, we continued to expand the known distribution and public awareness of badgers in the Cariboo Region. No additional burrowing habitat information was collected from that previously reported (see Packham and Hoodicoff 2006).

4.2 HAIR COLLECTION AND IDENTIFICATION OF INDIVIDUAL BADGERS

4.2.1 Hair Collection and DNA Viability

Pinned knaplock snags continue to be the most effective method of consistently collecting hair with follicles. The perimeter snags provided greater surface area for collecting multiple samples than snags set at individual burrow entrances.

While the pinned knaplock snags produced the highest viability of all methods used to date, comments from the DNA fingerprinting lab suggest that the viability of hair samples may be improved if the snags would pluck hairs rather than comb shed hairs, which carry far less DNA (Paetkau 2007). Using liquid adhesive to pluck hairs may be an alternative; however, it may be difficult to prevent soil from sticking to the adhesive if set inside of the burrow.

While we found that snagged hair consistently provided DNA with higher viability (i.e. greater chance of providing an identity) than shed hair, we still consider the use of shed hair an effective and cost-efficient method to remotely inventory badgers. Viability of DNA extracted from shed hairs may be improved by collecting hair during dry periods before moisture degrades the DNA. Lab techniques have improved so that DNA from a single hair follicle can be extracted and used to identify individual donors (Taberlet et al. 1996; Vigilant 1999). Hair collected from non-badger sources can be screened out in the lab during the pre-screening process using one badger-specific marker.

4.2.2 DNA Markers

Additional markers (*MP0182* and *MP0120*) tested this year significantly improve the power of the 6-locus marker system used previously (Packham and Hoodicoff 2006). This decreased the probability of two individuals with similar genotypes being assigned to one individual, or false recognition of multiple individuals from inconsistent genotyping of samples taken from the same individual (Paetkau 2007). Because marker *MP0182* did more to increase the power of the marker system than marker *MP0120*, the genetic lab recommends *MP0182* be included for a 7-locus marker system (with *Ma1, Tt1, Tt4, Tt2, Tt3, Mv72*) in subsequent analyses (Paetkau 2007).

Paetkau (2003) states that identification of individuals should be based on a minimum of 5-locus markers when expected heterozygosity of those markers is in excess of 0.77. Because the expected heterozygosity of all of the markers used in our study is less than 0.77 (Table 3.6), the overall power of the marker system used is still considered relatively low. Further tests of additional markers, such as *Ma-15, Gg-3,* and 39 markers recently published for European badgers (Frantz et al. 2003) is recommended.

4.3 POPULATION TRENDS

Our results suggest that there is a substantial badger population in the Cariboo region compared to those reported in other regions of the province (Weir et al. 2003; Newhouse and Kinley 2006). We continue to detect new individuals in the study area since 2003 as our snagging techniques have improved and we are receiving more visual reports from the public. Since the project began in 2003, we have identified “hotspots” of badger activity in the study area: River Lakes and Alberta Lakes area, Marmot Ridge Golf Course, the North Bonaparte Road, the Green Lake Gravel Pit, and the two maternal burrows west and northwest of 100 Mile House. With the continued increase in individual badgers detected, and observations of animals in areas where they were not observed at the beginning of the study, we believe that the population in the region is increasing.

We have limited information on family groups to date, although we have identified kits from 2 litters: 5 kits in 2005 and 4 kits in 2006. We have some indication of the dispersal potential of kits. A female kit born in 2005 was detected 67 km from the maternal burrow. Recent data from the East Kootenays (Newhouse and Kinley 2006) suggests that the average maximum dispersal distance of male kits (26.1 km, $n = 4$) is greater than that of female kits (11.0 km, $n = 6$, $p = 0.035$). In the future, we hope to document home range establishment for these kits to determine their settlement in relation to their parents. The results of DNA fingerprinting also suggest there could be some inbreeding in the population. Male M297 was the father of two litters (one in 2005 and one in 2006). Based on the genetic analyses, he may have sired a litter with one of his potential offspring (F507). Future genetic analyses should include a comparison of relatedness of the population, as additional individuals are identified.

Consistent with other regions in the province, roads are a significant source of mortality for badgers in the Cariboo. There appear to be key areas where badgers are at risk from road mortality. For example, two badgers were killed on Highway 97 near Marmot Ridge Golf Course. Mitigating road mortality has been a focus of recovery efforts in 2006, and will be the focus of research in 2007 (Section 5.4).

4.4 POPULATION ESTIMATORS AND STUDY DESIGN

Hair collection and DNA fingerprinting is a relatively new approach to conducting inventory of badgers in the province. Therefore, finding reliable methods of collecting hair from a low density population and developing appropriate genetic analyses were considered a priority to a robust study design to avoid violation of key assumptions. Consequently, we used simple estimators to calculate population abundance rather than more complex models. We consider the Jolly-Seber population estimates from 2004 and 2005 to be reasonably accurate, and although confidence intervals are large (65% and 55% of the estimated population size), the estimates concur with observations made during the study. While we did attempt to use more complex models in MARK, the difficulties we encountered (i.e. numerical convergence was not reached) were at least partially attributed to the lack of robust study design, relatively low rates of recapture and relatively high mortality rates.

Many assumptions required for open mark-recapture estimators were violated in our study. Since badgers occur at low densities, our primary objective was to develop reliable hair collection methods and determine abundance of badgers resident in the region. Our sampling strategy was opportunistic and relied on finding burrows with fresh sign, often expanding search efforts to find new burrows, violating the assumption of equal catchability. Predictably, our test of this assumption indicated that we are not trapping a representative sample of the population, and as a result, we may have over-estimated abundance. We also did not meet the assumption of equal survival rates for all animals, given the regular occurrence of highway mortality observed. Badgers living near and crossing the highway may be at a higher risk of mortality than badgers with home ranges that do not intersect busy roads. Finally, due to poor viability of many DNA samples, all animals that deposited hair were not recorded (i.e. “marks” were overlooked). Although both shed and snagged hair provide a means to identify individuals in the population, there is considerable difference in viability between these sources that should be considered in a more robust study design.

We recommend the following to improve study design for mark-recapture studies of badgers:

- Identify a core study area boundary that is consistent throughout the study, and ideally does not include areas of high mortality (e.g., away from busy roads);
- Prior to project initiation, develop a sampling strategy that samples a representative proportion of the study area (i.e. not biased by high activity areas), and provides some consistency of trap effort per unit area (e.g., snag a grid cell area for a pre-defined period); and,
- If sufficient samples can be collected, consider differentiating collection methods (i.e. snagged versus shed hair samples) for estimates of abundance.

4.5 DISTRIBUTION OF BADGERS AND MOVEMENTS

We continue to confirm that individual badgers in the Cariboo use large areas, despite apparently high densities in some areas (i.e. Alberta and River Lakes area). This may indicate that badgers are expanding their movements for mate and food searching, or juveniles are searching over large areas for a suitable home range (*jeffersonii* Recovery Team 2008). However, sizes of areas used were calculated with very few locations and do not represent true home ranges, habitat use, or illustrate travel corridors. A telemetry-based study is required to better understand use within home ranges and address the reason behind extended movements.

5.0 BADGER RECOVERY AND FUTURE RESEARCH

The results of the Cariboo Badger Research Project have led to a number of initiatives to conserve badger populations and their habitat. These activities are consistent with the key objectives identified in the Recovery Strategy (*jeffersonii* Recovery Team 2008), and are discussed in the following sections. We continue to actively participate in the *jeffersonii* Badger Recovery Team meetings. Roger Packham is currently co-chair of the team, and hosted the Recovery Team meeting in 100 Mile House (at Big Bar Ranch) in May 2007.

5.1 PROVINCIAL INVENTORY STANDARDS

Inventory methods developed during this project have contributed to updated inventory standards for badgers in B.C. (RISC 2007). Inventory protocols include the use of burrow surveys to identify badger activity, and collection of shed and snagged hair for DNA fingerprinting to determine relative and absolute abundance of badgers in a study area. We recommend the pinned knaplock snag sets at single burrow openings and around the perimeter of maternal burrows. The use of these methods to inventory badgers across the province should result in a better understanding of population size, genetic diversity, and potentially large-scale movements and estimates of genetic relatedness.

5.2 WILDLIFE HABITAT AREAS

A key objective of the *jeffersonii* Badger Recovery Strategy is to ensure suitable habitat for badgers and their prey. This can be accomplished on Crown lands by identifying Wildlife Habitat Areas where management is directed at maintaining or improving habitat for badgers.

We proposed 11 WHAs on Crown land in the Cariboo region in areas that we identified important badger habitat (Table 5.1). These included areas with concentrations of badger burrows, abundant prey resources and soils suitable for burrowing. We also proposed WHAs at maternal burrows and sites that had evidence of historic badger use, particularly those in unique areas such as isolated deposits of lacustrine soil. Maternal burrows were identified where there were observations of family groups (>1 badger) or obvious juveniles. Characteristics or evidence of a maternal den included larger than average burrows with large soil berms and signs of repeated use (e.g., tracks, fresh digging). We identified sites that were used historically as those with multiple old, collapsed burrows and with berms in front of entrances that were grown over with grass sod. Burrows in isolated habitat, e.g., burrows within grassland pockets surrounded by timber, were also incorporated into WHAs. These were delineated on maps using ecosystem type boundaries or existing infrastructures (e.g., roads, streams, cutblock boundaries), and were submitted for approval by the regional Wildlife Biologist (Julie Steciw, MoE). Many of these WHAs, and CCIB reserve parcels, will receive habitat restoration treatments in 2007 to reduce forest encroachment/in-growth to improve habitat for badgers and their prey (supported by Habitat Conservation Trust Fund and Interdepartmental Recovery Fund). These areas will be managed according to the Identified Wildlife Management Strategy (IWMS) to maintain habitat quality (Adams and Kinley 2004), and will be evaluated regularly to ensure that management objectives are being met (Newhouse et al. 2007).

Table 5.1. Wildlife Habitat Areas (WHAs) proposed for badgers in the 100 Mile House Forest District of the Cariboo region.

No.	WHA Name	Special Features	Area (ha)
1	Augustine	Grass knoll in timber, bear den	34.1
2	Komori	Lacustrine soil deposit	51.4
3	1200 Rd	Maternal burrow, sharp-tailed grouse lek site	39.4
4	Windmill	Maternal burrow, grass knoll in timber	99.4
5	Alberta Lake West	High density badger activity, historic use	92.7
6	Alberta Lake East	High density badger activity, historic use	53.9
7	McKinley Lakes	High density badger activity, historic use	70.3
8	Pollard Lake	High density badger activity, historic use	70.5
9	China Lake	Maternal burrow, range exclosure	87.3
10	River Lakes	High density badger activity, historic use	97.8
11	Hutchison Lake	Wetland habitat	75.4
		Total Area	772.2

5.3 HABITAT MANAGEMENT

We developed best management practices (BMPs) for badger habitat in the Cariboo region to guide managers and ensure good range and riparian habitat conditions to maximize prey numbers and diversity (Hoodicoff 2004, Hoodicoff 2005). Management recommendations support the general wildlife measures for badgers in the IWMS (Adams and Kinley 2004), and address other activities that impact badger habitat not covered by the IWMS on Crown and private lands. These include: a) range practices, b) agricultural cultivation, c) forest in-growth and encroachment, d) forest harvesting, e) urban development, f) road construction and maintenance, and g) golf course management. Because badgers use large areas, these WHAs may maintain grassland habitat for other species, including sharp-tailed grouse, blue grouse and numerous species of ground nesting waterfowl that share badger habitat.

5.4 ROAD CROSSING MITIGATION

Another objective of the *jeffersonii* Badger Recovery Strategy is to increase badger survivorship and recruitment. This may be accomplished by

- Increasing the likelihood of badgers safely crossing roads
- Decreasing habitat suitability near roads for badgers and their prey
- Decreasing traffic speeds in areas of high badger activity, and

- Increasing the appreciation of badgers, their prey and their habitat.

Recovery efforts conducted during the project to date have focused on road mitigation to increase the likelihood of badgers safely crossing roads. In response to several badger roadkills, we erected 5 badger road crossing signs warning motorists on Highway 97 between 70 Mile House and 150 Mile House (Appendix A, Photo 7). Highway mitigation measures have been suggested for badgers in areas along Highway 97 being upgraded. These include culvert crossings under the highway, and the placement of concrete roadside barriers with drainage holes for badger egress off of the highway. The efficacy of signs and other mitigation measures to reduce badger road mortality will be monitored in the future.

Research on the hazards of vehicles and roads for badgers will begin in 2007 with financial support from the B.C. Ministry of Transportation. The focus of this work is to study badger crossing habits and develop mitigation measures to reduce highway mortality. Primary objectives will be to identify areas of high badger activity where conflict with traffic is likely to be an issue using radio-telemetry, focal monitoring of individuals, and analysis of associated habitat characteristics.

6.0 SUMMARY

The Cariboo Region Badger Project was initiated in 2003 to determine the distribution and abundance of badgers at the northern periphery of their range to support recovery activity for the species. To meet these objectives, we collected burrow locations and observations of animals reported by the public, and collected hair (snagged and shed) for DNA fingerprinting. Using this information, we were able to identify individual badgers, estimate areas used and document movements for a better understanding of badger ecology in the region.

Since 2003, we have documented a total of 736 burrows and 101 badger sightings in seven ecosections. A total of 51 badgers (23 females, 28 males) have been identified in the

Cariboo region based on 315 DNA samples. These include 2 litters, 5 kits in 2005 and 4 kits in 2006, from different mothers but likely the same father. To date, we have detected 9 badger mortalities, including one accidental trapping, 8 highway mortalities, and we are aware of at least one more unconfirmed road mortality.

Despite the road mortalities, we suspect that the badger population may be increasing in the region as there more individuals detected each year, and observations of animals are expanding into new areas. However, the Jolly-Seber estimates of population abundance in the study area were not significantly different in 2004 (range 18.3 to 34.1) and 2005 (range 26.6 to 44.5). The minimum number of badgers alive in the study area in 2006 is 26.

Remote hair collection proved an effective way to collect genetic information (hair follicles) for DNA fingerprinting. The pinned knaplock snags consistently provided a greater percentage of samples successfully assigned to individual badgers than other methods used. This was attributed to pulling sufficient hair from the badger and avoiding exposure of hair samples to moisture (i.e. inclement weather). While snagged hair provided more viable samples, shed hair were a cost-efficient source of genetic material for DNA fingerprinting, and could be collected without a formal methodology. Two additional genetic markers tested this year improved the 6-locus marker system used previously (Packham and Hoodicoff 2006). However, overall power of the marker system used is still considered relatively low. Recommendations for future testing include adding *MP0182* for a 7-locus marker system (*Ma1, Tt1, Tt4, Tt2, Tt3, Mv72* and *MP0182*). As more individuals are identified in future inventory programs, and in other regions, additional markers should be developed. Herein, we make recommendations to improve the design of future mark-recapture studies of badger populations.

A number of recovery activities in the Cariboo region have resulted from this research. Hair snagging protocols have been incorporated into provincial standard methods for estimating relative and absolute abundance of badgers. Eleven WHAs have been proposed on a total of 772 ha of Crown land. These areas will be managed to maintain and improve habitat conditions for badgers under the Forest and Range Practices Act. Many of these WHAs, and CCIB reserve parcels, will be treated in 2007 to reduce forest encroachment/in-growth to improve habitat for badgers and their prey. In response to roadkills recorded during the project, 5 badger road crossing signs to warn motorists were erected on Highway 97 between 70 Mile House and 150 Mile House. In 2007, research will focus on the hazards of roads for badgers with financial support from the B.C. Ministry of Transportation and the B.C. Conservations Corps.

7.0 REFERENCES

Adams, I. T. and Kinley, T. A. 2004. Identified wildlife management strategy account for badger. BC Ministry of Water, Lands, and Air Protection. Victoria, BC.

Cooch, E. and White. 2006. Using MARK: a gentle introduction. 5th Edition. On-line at http://www.phidot.org/software/mark/docs/index.html.

Creel, S., Spong, G., Sands, J.L., Rotella, J., Zeigle, J., Joe, L., Murphy, K.M., and Smith, D. 2003. Population size estimation in Yellowstone wolves with error- prone noninvasive microsatellite genotypes. Molecular Ecology 12: 2003-2009.

Davis, C.S. and Strobeck, C. 1998. Isolation, variability, and cross-species amplification of polymorphic microsatellite loci in the Family mustelidae. Molecular Ecology **7:** 1776-1778.

Environmental Systems Research Institute (ESRI). 1998. ArcView Geographical Information Systems Software Version 3.1. Environmental Systems Research Institute Inc.

Frantz, A.C., Pope, L.C., Carpenter, P.J., Roper, T.J., Wilson, G.J., Delahay, R.J., and Burke, T. 2003. Reliable microsatellite genotyping of the Eurasian badger (*Meles meles*) using faecal DNA. Molecular Ecology 12**:** 1649-1661.

Frantz, A.C., Schaul, M., Pope, L.C., Fack, F., Schley, L., Muller, C.P., and Roper, T.J. 2004. Estimating population size by genotyping remotely plucked hair: the Eurasian badger. Journal of Applied Ecology 41: 985-995.

Hoodicoff, C.S. 2004. Description and management of badger habitat in the Cariboo region. Ministry of Water, Land and Air Protection. Victoria, British Columbia. Victoria, B.C.

Hoodicoff, C.S. 2005. Cariboo Region Badger Project Year End Report. Habitat Conservation Trust Fund Project #5-119. Prepared for Roger Packham, Ministry of Water, Land and Air Protection, 100 Mile House, B.C.

jeffersonii Badger Recovery Team. 2005. Draft National recovery strategy for the American badger, *jeffersonii* subspecies (*Taxidea taxus jeffersonii*). Recovery of Nationally Endangered Wildlife (RENEW). Ottawa, Ontario.

Jordan, M. 2007. Personal communication (with David Paetkau, Wildlife Genetics International Ltd.) Ph.D. candidate, University of California, Berkeley.

Krebs, C.J. 1989. Ecological Methodology. Harper & Row Publishers, New York, NY.

Kyle, C.J., Weir, R.D., Newhouse, N.J., Davis, H., and Strobeck, C. 2004. Genetic structure of sensitive and endangered northwestern badger populations (*Taxidea taxus taxus* and *T.t. jeffersonii*). Journal of Mammalogy 85: 633-639.

Leslie, P.H., Chitty, D., and Chitty, H. 1953. The estimation of population parameters from data obtained by means of the capture-recapture method. III. An example of the practical applications of the method. Biometrika 40: 137-169.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37: 223-249.

Mowat, G. and Paetkau, D. 2002. Estimating marten *Martes americana* population size using hair capture and genetic tagging. Wildlife Biology 8: 201-209.

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

Newhouse, N.J. and Kinley, T.A. 1999. Update COSEWIC status report on the American badger *Taxidea taxus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario.

Newhouse, N.J. and Kinley, T.A. 2006. East Kootenay Badger Project 2005-2006 Progress Report: Ecology, Translocation, Communication, Sightings and Habitat Use. Sylvan Consulting Ltd., Invermere, B.C.

Newhouse, N.J., Kinley, T.A., Hoodicoff, C., and Page, H. 2007. Wildlife Habitat Area Effectiveness Evaluations: Protocol for Monitoring the Effectiveness of Badger Wildlife Habitat Areas, Version 1.2. Prepared for Ministry of Forests and Range, Victoria, B.C.

Packham, R. and Hoodicoff, C. 2006. Cariboo Region Badger Project: Summary Report 2003-2005. Ministry of Environment, 100 Mile House, B.C. and Summit Environmental Consultants Ltd., Vernon, B.C.

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

Paetkau, D. 2007. Letter to Roger Packham dated February 20, 2007 (Re: WGI project g0042, BC Project 2981029 Cariboo Badger). Wildlife Genetics International Ltd., Nelson, B.C.

Piggott, M.P. and Taylor, A.C. 2003. Remote collection of animal DNA and its applications in conservation management and understanding the population biology of rare and cryptic species. Wildlife Research 30: 1-13.

Poole, K.G., Mowat, G., and Fear, D.A. 2001. DNA-based population estimate for grizzly bears in northeastern British Columbia, Canada. Wildlife Biology 7: 65-75.

Rahme, A. H., Harestad, A. S., and Bunnell, F. L. Status of the badger in British Columbia. 1995. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, BC.

Resources Information Standards Committee (RISC). 2007. Inventory Methods for Medium-sized Territorial Carnivores: Badger. Standards for Components of British Columbia's Biodiversity No. 25a. Ministry of Environment, Ecosystems Branch. Victoria, B.C.

SPSS Inc. 1998. SYSTAT Software, Version 8.0. SPSS Inc.

Steen, O.A. and R.A. Coupe. 1997. A Field Guide to Forest Site Identification and Interpretation for the Cariboo Forest Region. Land Management Handbook No. 39. B.C. Ministry of Forests, Resource Branch. Victoria, B.C.

Taberlet, P., Griffin, S., Goossens, B., Questiau, S., Manceau, V., Escaravage, N., Waits, L.P., and Bouvet, J. 1996. Reliable genotyping of samples with very low DNA quantities using PCR. Nucleic Acids Research 24: 3189-3194.

Taberlet, P. and Luikart, G. 1999. Non-invasive genetic sampling and individual identification. Biological Journal of the Linnean Society 68: 41-55.

Vigilant, L. 1999. An evaluation of techniques for the extraction and amplification of DNA from naturally shed hairs. Biological Chemistry 380: 1329-1331.

White, G.C. 2000. MARK software, version 4.3. Dept. of Fish and Wildlife, Colorado State University. Fort Collins, CO.

Weir, R.D., Davis, H., and Hoodicoff, C.S. 2003. Conservation strategies for badgers in the Thompson & Okanagan Regions: Final Report, March 2003. Habitat Conservation Trust Fund, Artemis Wildlife Consultants, Armstrong, BC.

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