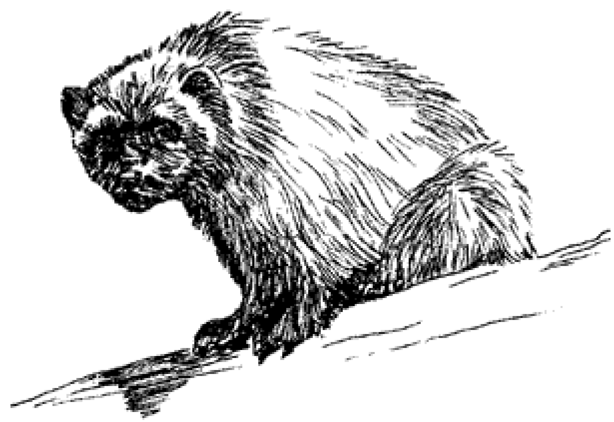
ALBERTA WOLVERINE EXPERIMENTAL MONITORING PROJECT

2004-2005 ANNUAL REPORT



Alberta Wolverine
Experimental Monitoring Project

2004-2005 Annual Report

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DISCLAIMER

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TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY

This report summarises data collected in 2004-2005, provides a preliminary analysis of these data, updates discussion and recommendations for wolverine monitoring from previous reports, and outlines plans for the next year of the project.

Wolverine occurrences were remotely monitored across the foothills of central Alberta, Canada between December 2004 and March 2005. We deployed 60 monitoring stations fitted with hair traps for noninvasive genetic tagging; a random subsample of 11 of these hair-trapping stations were fitted with infrared-triggered remote camera systems to assess detection rates of hair stations. We logged 5,665 hair-trap nights and 697 camera-trap nights.

Ten mammal species were detected at monitoring stations, ranging in size from flying squirrels to grizzly bears. Detection rates for wolverine were higher than in previous sampling years. Wolverine were detected at 7 of 60 baited stations (11.7%), compared with 2.2% of stations in 2003-2004. These detections represented five individuals, including 2 males and three females. Further data are required to achieve an accurate density estimate; our rough estimate from this year's data is 1 wolverine per 94 km^2, assuming that stations drew in animals from within a 2-km radius.

Our results are indicative of the very low densities at which wolverine exist in the foothills of Alberta. Further monitoring will continue in 2005-2006 using existing protocols and study sites to assess the amount of interannual variability in wolverine and other furbearer detection rates. We will use these detection rates, and estimates of temporal variance associated with them, to provide final recommendations for a wolverine population monitoring program for Alberta.

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CHAPTER 1. BACKGROUND AND RATIONALE

The Uncertain Status of Wolverines in Alberta

The management of species-at-risk in Canada has emerged with new vigour following the 2003 proclamation of SARA, Canada's Species At Risk Act. As wildlife species were re-scrutinised under this new federal mandate, it was found that many species - some believed to be at risk, some heretofore ignored - were lacking even the basic population or trend data for an accurate assessment. A prime example of this oversight is the wolverine.

The wolverine (*Gulo gulo*) is a Mustelid, taxonomically and genetically related to fisher, marten, weasels and skunks. Wolverines were once distributed across the circumboreal biogeographic zones in Eurasia and North America, inhabiting boreal, tundra, and montane habitats. In North America, the traditional small native harvest of wolverines for pelts was dramatically increased with European colonisation, and subsequent demands for prime Canadian furs. As a result, wolverines were extirpated from many areas in eastern Canada; those that remain are listed as *Endangered* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2003). Lighter historical harvest pressures, combined with less accessible montane and tundra refugia, have allowed the wolverine to fare better in western Canada. This population has been estimated at 13,000 individuals. This assessment is remarkably dubious as "there are no data on overall population trends other than those provided by local knowledge and harvest monitoring programs" (COSEWIC 2003). These sources are unfortunately not conducive to a rigorous estimate of minimum population size, population trend, and estimates of population sustainability. The western wolverine was assessed as a species of *Special Concern* by COSEWIC (2003), acknowledging the lack of data pertaining to this elusive species, and the potential threat of extirpation indicated by wolverines' life-history traits, suspected sensitivity to human development, and historical predisposition to widespread population reduction, range retraction, and ultimately extirpation.

In the Province of Alberta, wolverines inhabit the mountains, foothills, and boreal plain, but in unknown numbers that are suspected to be very low and declining (Petersen 1997). The Government of Alberta has designated this species *"May be at Risk"* (Alberta SRD 2000), an appellation that denotes potential vulnerability to extirpation but a fundamental lack of information required for a risk assessment. There has never been an inventory of wolverine population size, distribution, demographics, or habitat use in the montane or boreal regions of the Province. Analysis of historical harvest records do suggest that wolverine numbers have declined dramatically over the last century (Poole and Mowat 2001), and given what we know of wolverine population biology, this is cause for alarm.

Wolverine Life-History and Ecology

The wolverine is a scavenging carnivore. Winter forage consists largely of ungulate carcasses; in other seasons wolverines feed on ungulates, small rodents, and snowshoe hares (Hornocker and Hash 1981; Banci and Harestad 1990). Food availability - most notably the availability of ungulate carcasses in winter (Persson and Willebrand unpubl. data) - coupled with habitat suitability are likely primary drivers of wolverine habitat use, as wolverines are highly susceptible to fluctuations in foraging opportunities (Weaver *et al.* 1996) and anthropogenic disturbance.

Den sites used for the rearing of young have also been identified as key elements of wolverine habitat. In montane regions den sites are established in snow tunnels; in montane/ foothills regions den sites are located under fallen trees and boulders (Magoun and Copeland 1998). Habitat selected for denning in boreal regions, with less rugged topography, is unknown. In fact, with the exception of some description of wolverine cache sites and travel routes (Wright and Ernst 2004a,b), no data exist on habitat use by boreal wolverines.

Wolverines are intrinsically scarce. They have low reproductive rates, low juvenile survivorship (Banci and Harestad 1988; Petersen 1997), and late development rates, which result in low population sizes. Wolverines are solitary and wide-ranging, and naturally exist at low densities. Estimates of density range from 1 wolverine per 65 km^2 in Montana (Hornocker and Hash 1981) to 1 wolverine per 177 km^2 in the Yukon (Banci and Harestad 1990). This population structure is an adaptation to infrequent and widely dispersed food resources and the resulting necessity for extremely large home ranges that are highly variable (Whitman *et al.* 1986; Landa *et al.* 1998; Vangen *et al.* 2001). Unfortunately, this population structure also results in a marked inability of wolverines to withstand additive mortality, whether from fur harvest or habitat loss, as evidenced by the history of extirpation across its range.

The Rationale for Monitoring Alberta Wolverine Populations

Wolverines' large home-range requirements, low densities, and low productivity, make them potentially sensitive to overexploitation. They rely on large geographic areas encompassing the full spectrum of seasonal habitat requirements, while providing enough variability in food availability that natural fluctuations are buffered. Therefore, anthropogenic activity that reduces available habitat may have repercussions for already low wolverine mortality and survivorship, and hence impact abundance and distribution.

Currently, timber harvesting, oil and gas activity, and a limited wolverine fur harvest all occur in Alberta's boreal forest. However, wolverines' response to forest harvesting and other anthropogenic disturbance in Alberta is completely unknown (Fisher and Wilkinson 2002). In British Columbia, wolverines appear to be vulnerable to human development and are in decline (J. Krebs and E. Lofroth, pers. comm.). In Montana, wolverines occurred most often in mature and old stands, least often in young dense stands, and never in clear-cuts (Hornocker and Hash 1981). Wolverines avoid human settlements and seem to be susceptible to disturbance, particularly during the denning period, as humans cause a significant portion of recorded wolverine mortalities (see review in Weaver *et al.* 1996). That the extirpation of eastern wolverines was concomitant with human population growth in that region cannot be argued. As the areas formerly providing refugia - the western montane and boreal regions - are developed, it is possible wolverines here may experience similar declines.

Species-at-risk assessment and informed landscape management is required to mitigate potentially adverse effects of anthropogenic activity on wolverines in Alberta. However, for appropriate assessments to be conducted and an effective management plan to be created, we require reliable estimates of population size, home range size (for density estimates), immigration and emigration rates, reproductive rates, and recruitment rates. Currently, none of this information has been garnered in Alberta. In short, wolverines are scarce, elusive, and difficult to research.

Objectives of the Alberta Wolverine Experimental Monitoring Project

Our lack of knowledge of Alberta wolverine distribution and abundance is primarily due to this difficulty. Obtaining adequate sample sizes from this rare, low-density, highly vagile species presents a logistic and scientific challenge - a challenge shared with other jurisdictions housing wolverine populations, such as Scandinavia (Flagstad *et al.* 2004). Noninvasive genetic sampling (Taberlet *et al.* 1999) holds promise as an inexpensive method for obtaining replicated data on wolverine distribution, population size, dispersal distances, and density (Flagstad *et al.* 2004). This technique may also be used over the long-term within the framework of a monitoring program, to provide information on wolverine population trends.

However, establishing a rigorous and useful monitoring protocol for low-density animals is difficult, as the design requirements of new protocols are largely unknown (Kendall *et al.* 1992). As we have no pilot data on Alberta wolverine distribution, density, and coefficients of variation, we have no starting point from which to design a statistically rigorous monitoring program. No reliable and cost-effective methods for tracking wolverine populations in Alberta currently exist. This project attempts to address this need.

The goals of the Alberta Wolverine Experimental Monitoring project are:

Phase I (2002-3): to assess and calibrate noninvasive genetic tagging as a method for long-term population monitoring, by examining the relative efficacy of hair trapping with remote camera systems to reliably detect wolverines;

Phase II (2003-5): to examine and assess the experimental design requirements of a wolverine remote monitoring program; and

Phase III (2005-7): to provide preliminary data on wolverine distribution, density, probabilities of occurrence, and coefficients of variation that will pilot the implementation of a larger statistically rigorous Province-wide wolverine monitoring program.

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CHAPTER 2: STUDY AREA AND METHODS

The Alberta Foothills Study Area

Monitoring for wolverine in 2004-5 occurred in the foothills and montane regions of Alberta. Sixty (60) stations were established, generally following the Forestry Trunk Road between south of Hinton to north of Grande Cache (Figure 1). The foothills run northwest to southeast along the front range of the Rocky Mountains, with moderate topography and elevation ranging from 1200 m to 1600 m. Coniferous forest 80-120 years old (*Pinus contorta, Picea glauca, Picea mariana*, and *Abies balsamea*) are the dominant forest type in this region, with some small deciduous (*Populus tremuloides, P. Balsamifera*) stands occurring throughout. Younger fire- or harvest-origin stands are embedded within this matrix. Our study area was most commonly mixed mature lodgepole pine (*Pinus contorta*) with white spruce (*Picea glauca*), or mixed spruce-fir (*A. balsamea*). Small stands of black spruce (*Picea mariana)*, with forest floors dominated by Labrador tea (*Ledum groelandicum*) and mosses (*Sphagnum spp*), occurred in low-lying areas. Pine and mixed stands were often fairly open, with a sparse alder (*Alnus crispa*) understorey, forest floors dominated by *Pleurozium schreberi, Hylocomnium splendens* and *Ptilium crista-castrensis* mosses, and frequent standing snags throughout.

Site Selection for Monitoring Stations

Within this large study area, monitoring stations were established using a stratified systematic approach. Stations were a minimum of 3 linear km apart to reduce the probability of pseudoreplication (Hurlbert 1984) resulting from one individual being detected at several sites. Stations were a minimum of 50 m from access roads. Within this roughly systematic structure, stations were located at points of high elevation relative to the local landscape, where wolverines are suspected to travel and where bait scent dispersion is most effective. Stations were located in all forested stand types. Areas where industrial activity was currently occurring were not sampled. In addition, areas where access was poor were not sampled; this was a logistical decision that balanced effort and return, though these low-access areas are potentially high quality wolverine habitat.

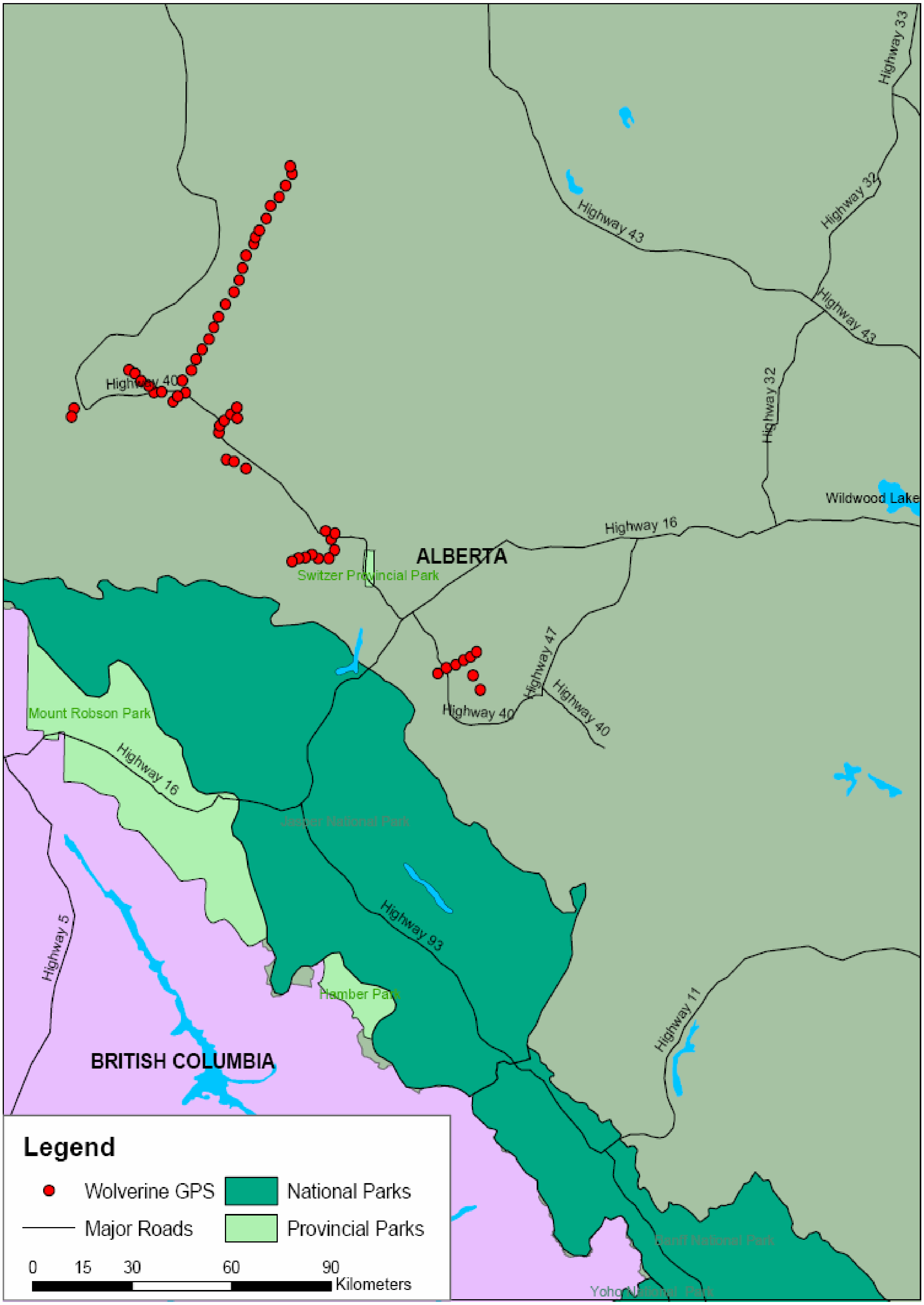

Figure 1. West-Central Alberta. Monitoring stations, indicated as red circles, were placed in the montane and foothills regions between Ram River and Grande Cache.

Wolverine Monitoring Methodology

The power of a new monitoring protocol to statistically and accurately detect a change in population size needs to be assessed against other techniques (Kendall *et al.* 1992). Classic mark-recapture experiments use the measure *trappability* to assess the accuracy of population estimates (Krebs and Boonstra 1984); an analogue for remote detection methods such as hair trapping, is required. In Fisher (2003), we attempted to assess detection probabilities of three different monitoring techniques – snow tracking, hair trapping, and camera trapping. We found that snow tracking did not have a sufficiently high detection rate to allow for adequate sample sizes, making trapping the preferred method. In Fisher (2004), we evaluated detection rates of hair traps versus camera traps; we found that hair trapping consistently undersampled animals visiting bait stations, thereby producing a unidirectionally biased abundance estimator. We recommended the use of hair trapping and camera traps together to construct a detectability correction factor. In 2004-2005, we implemented a monitoring protocol whereby all stations were fitted with hair traps, and a subset of these were fitted with camera traps.

Noninvasive genetic tagging: Hair capture

Noninvasive genetic tagging has recently become an accepted and widely used technique for remotely monitoring mammal populations, such as bears (Woods *et al.* 1999; Mowat *et al.* 2005) and marten (Mowat and Paetkau 2002). Hair samples taken from animals, if the follicle is present, can yield DNA samples. These can be amplified, identified to species by genotyping and matching against a reference library, and even assigned to individuals using microsatellite analysis (for discussion see McKelvey and Schwartz 2004a and 2004b). Hair trapping can yield low-cost and high-return data on distribution, relative abundance, and home range estimates. Mowat (2001) suggested this may prove to be an efficient method for remotely monitoring wolverine populations in Alberta.

In this year of the experimental monitoring project, we implemented a hair trapping protocol developed in Fisher (2004). At each monitoring station we selected a tree 10 cm – 20 cm in diameter, at least 2 m from other trees. We cleared branches from the lower bole of the tree, and wrapped 10 m - 15 m of high-tensile steel barbed wire around the tree, from the base to 2 m up the bole. Immediately above the wire (*ca.* 2.2 m up the bole) we nailed a full beaver carcass, and *ca.* 10 mL of O'Gorman's LDC Extra scent lure (O'Gorman's Co., Montana, USA).

We visited hair-snagging stations monthly between December 15, 2004 and April 15, 2005. Hair samples were collected using sterile procedures, placed in paper envelopes, and stored at *ca.* 10^{o}C in a standard kitchen refrigerator.

Genetic analysis of hair samples

All hair samples were sent to Wildlife Genetics International (WGI; Nelson, British Columbia, Canada) for genetic analysis. DNA was extracted from hairs using QIAGEN's DNEasy Tissue Kits (D. Paetkau, WGI, pers. comm.). DNA was then analysed for species identification; this involved a sequence-based analysis of the 16S rRNA, mtDNA gene (*sensu* Johnson and O'Brien 1997) that was then compared against a DNA reference library of all known mammal species expected to be found in the foothills and boreal forest. Identification of hair to species provided a presence-absence measure for furbearer species across our sampling transect.

Those hair samples identified as wolverine were analysed using microsatellite analysis to determine the number of unique individuals. Seven (7) markers developed for wolverines were used, a number considered adequate for genetic capture-mark-recapture studies (Paetkau 2004).

Camera traps

In the same sense as non-detection cannot be construed as an 'absence' in a standard presence-absence survey, neither does a lack of hair indicate that wolverine have not been present at a hair-snagging station. An estimate of hair detection probability is required to assess potential bias in site occupation probability estimators.

To assess this bias for our tree-trunk hair traps, camera traps were installed at eleven (11) randomly subsampled monitoring stations. Camera traps have been used as a low-cost alternative to livetrapping for a variety of other carnivorous species (*e.g.* Jones and Raphael 1993; Karanth 1995; Kucera *et al.* 1995; York *et al.* 2001; Bridges *et al.* 2004). In addition to calibrating wolverine detection rates *via* hair capture, camera trap data can be used as another relative index of wolverine abundance.

Trailmaster™ 1550 Active Infra-red Remote Camera Systems (Goodson and Associates Inc., Lenexa, Kansas) were installed at two trees aligned with the hair snag tree. These systems consist of a Canon A1 Sureshot camera, loaded with Provia 400F DX-coded 36-exposure 35-mm slide film, wired to an infrared (IR) beam receiver, placed *ca.* 6 m across from an IR transmitter. The IR transmitter and receiver were arranged on aligned trees such that the IR beam was *ca.* 15 cm under the bait. In principle, when an animal climbs the baited tree, it breaks the beam; the IR receiver notes this in a log, and sends a signal to the camera to take a picture. Trailmaster Receivers were set to record an event if the beam was broken for 5 pulses (0.25 seconds); we set a 5-minute camera delay to extend the sampling period and avoid multiple pictures from non-target animals. Film was checked and changed once a month. Slide pictures were analysed for species present, and compared with hair capture results.

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CHAPTER 3: RESULTS OF REMOTE WOLVERINE MONITORING

Sampling Success of Hair and Camera Traps

Monitoring stations were operational from December 7, 2004 to March 15, 2005. Our 60 monitoring stations were established over a linear transect in excess of 500 km. The total area sampled in this study varies as a function of area of influence (AOI) of the monitoring stations (see also Fisher 2004). Calculating the AOI - the area within which a randomly located animal will sense the attractant, possess a non-zero probability of moving towards the station, and be detected – is difficult. The AOI depends on the nature of the bait used, ambient temperature, prevailing winds, food availability, the species being attracted, and intra-species variability. Accurate tracking information is required to accurately estimate mean and standard deviation for an AOI; as we lack these data, the AOI can only be postulated. We make a conservative assumption that the AOI for our monitoring stations encompasses a 2-km radius, and thus we sampled a 750 km^2 area.

Hair capture

We logged 5,665 hair trap nights. Hair traps were assumed to be fully functional from the day of deployment to the final collection period. In some cases, trap checks revealed that bait had been missing for an unknown period of time; however, pieces of carcasses, scent lure, and other attractants usually remained at the site to attract animals. Camera data revealed that animals returned to a site even after most of the bait had been removed. Therefore, for purposes of trap-night calculation, the assumption was made that functionality of a hair trap was constant throughout the sampling period.

We collected 312 hair samples from 59 of 60 stations in 2004-2005. This was a dramatic improvement from 54 hair samples collected from 29 of 90 stations in 2003-2004. Of the 312 hair samples collected, 10 did not contain enough material to allow for extraction of DNA. Of the 302 hair samples from which DNA was extracted, 54 failed to produce useful data due to lack of viable material. Nine samples could not be identified to species as genotyping did not match any known reference species. The remaining 239 hair samples were identified to species (Table 1).

Camera traps

We deployed eleven (11) cameras at fixed stations between November 2004 and April 2005. One of these stations was disturbed by anthropogenic activity and was moved partway through the season (resulting in 12 stations identified in the analysis). Cameras were active for a gross total of 1039 trap nights; malfunctions resulted in a net total of 697 trap nights. Species identified at monitoring stations using camera data (Table 2) include marten (8 stations), fisher (8), red squirrels (2), flying squirrels (2), cougar (1), and lynx (1). For the first time in three years of study, wolverine were not detected at a camera site.

Wolverine Detections

Wolverines were detected by hair trapping at seven monitoring stations (Table 3). Microsatellite analysis revealed five individuals – two males and three females. The sample size is too low to allow analysis of relatedness or population genetics, but the range of genetic variability is consistent with samples obtained from the North West Territories (D. Paetkau, WGI, pers.comm.).

Four of the five wolverines were detected at a cluster of four stations, over a > 15 km area, northeast of Grande Cache. These detections were spread out over three sampling periods, suggesting these individuals were not transiting through the area but rather were residents. The sizeable number of wolverines occurring together suggests this is a family unit consisting of a female with 3 kits, but this remains conjectural pending sufficient genetic data to allow analyses of relatedness. The fifth wolverine, a male, was detected at three stations over a > 15-km area. These detections occurred at different sites than the previous four wolverines, and occurred within a single sampling period, suggesting the individual may have been transiting through the area.

Assessment of the Reliability of Detections

Detectability correction factor

As in 2003-2004, hair trapping was not as effective as camera trapping at detecting the presence of an occurring species. Omitting tree squirrels from the dataset, (as neither cameras nor hair traps were designed to reliably capture these species), there were 20 instances where species were detected at monitoring stations fitted with cameras (12 stations with 7 stations detecting > 1 species). Both the hair traps and camera traps detected the same species in only 11 instances (Table 4). Cameras detected a species when hair trapping did not, in 7 cases; the reverse occurred in 2 cases due to camera malfunction.

A sign test (Zar 1996) suggested that cameras were significantly better at detecting the presence of a mammal species at a station than were hair traps ($n = 9$; $X \leq 2$, $X \geq 7$; $p = 0.176$). Our sample size was small and this analysis was strongly influenced by the one camera malfunction in one sample period. If we excluded these two cases, the *p* value decreases ($n = 7$; $X \leq 0$, $X \geq 7$; $p = 0.016$). These results suggest that hair traps are reliably detecting mid-size and large furbearer species occurring at monitoring stations 11 out of 18 times (61.1% of the time). If this is the case, then a detectability correction factor of ***1.6*** should be applied to hair-capture detection rates to provide more reliable estimates of occurrence. This is comparable to a detectability correction factor of ***1.8*** calculated from 2003-2004 data (modified from Fisher 2004).

Table 1 Number of hair samples obtained, by species.

Species	**Number of samples**
flying squirrel *Glaucomys sabrinus*	2
black bear *Ursus americanus*	1
grizzly bear *Ursus arctos*	1
cougar *Puma concolor*	3
lynx *Lynx canadensis*	14
fisher *Martes pennanti*	111
marten *Martes americana*	68
red fox *Vulpes vulpes*	2
coyote *Canis latrans*	3
wolf/dog *Canis lupus or C. familiaris*	2
wolverine *Gulo gulo*	31

Table 2 Species present at each monitoring station as identified by hair traps and camera traps. Results are an integration of data gathered at camera stations between December 2004 and April 2005.

Station	Species detected by hair traps	Species detected by camera
100C	Marten	Marten Fisher
104C	Unknown	Marten
112C	Fisher	Fisher
116C	Fisher	Fisher Marten
125C	Fisher	Fisher Marten Cougar Flying squirrel
126C	Fisher	Fisher
133C	Flying squirrel	Flying squirrel Red squirrel
138C	Fisher	Fisher Lynx
139C	Marten	Marten
141C	Fisher Marten	Fisher Marten
144C	Marten	Marten
147C	Marten Lynx Fisher	Marten Red squirrel Red fox

Table 3 Individual wolverines detected at monitoring stations.

Wolverine individual ID	Gender	Stations where individual was detected	Month detected
1098A	M	F98	January 2005
		F96, F97	February 2005
2098A	F	F96, F98, F99	February 2005
3096C	M	F96, F97	February 2005
		F98	March 2005
3097C	F	F97	February 2005
		F98, F99	March 2005
3106A	F	F106, F107, F109	March 2005

Species Detection Rates

Twelve mammal species were detected at monitoring stations (Table 4). Detection rates – the percentage of occurrences of a species over the number of monitoring stations – varied considerably. Fisher were the most ubiquitous, followed closely by marten; wolverine were third-most common, a marked increase from previous years. Black bear, grizzly bear, cougar, and red fox were only rarely detected (2.1%). However, it should be emphasised that monitoring stations were designed to most reliably detect tree-climbing mustelids, including fisher, marten, and wolverine. Within-year between-species comparisons of frequency are not warranted.

Table 4 Unadjusted species detection rates. The percent of stations at which species were detected, out of a total of 60 monitoring stations. Detections have been integrated across time (December 2004 – March 2005).

Species	**Detection rate (%)**
flying squirrel *Glaucomys sabrinus*	3.3
black bear *Ursus americanus*	1.7
grizzly bear *Ursus arctos*	1.7
cougar *Puma concolor*	1.7
lynx *Lynx canadensis*	8.3
fisher *Martes pennanti*	48.3
marten *Martes americana*	46.7
red fox *Vulpes vulpes*	1.7
coyote *Canis latrans*	3.3
wolf/dog *Canis lupus or C. familiaris*	3.3
wolverine *Gulo gulo*	11.7

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CHAPTER 4: LESSONS LEARNED, AND LESSONS YET TO COME

A Review of Wolverine Monitoring Methods

This year's implementation of the wolverine monitoring protocol marks the most successful phase of the project. In 2002-2003, the 'hair corral' method of wolverine monitoring suggested by Mowat (2001) was tested and found to be unreliable due to refusals by wolverine to enter the corral (Fisher 2003). One wolverine was detected in a partial photograph. In 2003-2004, the 'tree hair trap' method was tested with different baiting and sampling effort regimes. We found that unbaited stations treated with scent lures did not attract mammals. Stations baited with whole beavers were more successful at attracting mammals than scent-lure stations (Fisher 2004). We also found that at least monthly sampling was required to prevent loss of hair and camera data. Several mammal species were detected, and we established that noninvasive genetic tagging underestimates frequency of occurrence by about 40%. One wolverine was detected in a camera trap.

Building on these lessons, this year we implemented a monitoring protocol that successfully detected wolverine at multiple stations. This method also yielded considerable data on frequency of occurrence of other mustelid species, and some data on other forest mammals. Our hair pole method still undersamples frequency of occurrence by about 40%; based on two years data, we are confident that a detectability correction factor of *ca.* 1.6 can be applied to adjust for the unidirectional bias in wolverine abundance estimates.

With this finalised monitoring protocol in place, we now require some replication of monitoring efforts through time to assess interannual variability in detection rates. In 2005-2006, we are continuing with the final-phase implementation of noninvasive wolverine monitoring in the foothills of Alberta. Monitoring will occur using the same methods in the same sample locations, thus providing data for calculating coefficient of variation to be used in a power analysis for a larger long-term program (*q.v.*). These future data will also be used to examine variability in wolverine density estimates, to assess their variability across years.

Estimates of Wolverine Density

The wolverine detection rate in this phase of the project (11.7%) was higher than last years' (2.2%). As this detection rate was obtained by hair trapping, application of the correction factor is warranted, yielding an estimated occurrence rate of (1.6)*(11.7) = 18.7%. As we detected 5 individuals, and we assume we undersampled unique individuals by this same fraction, then we can estimate that (5)*(1.6) = 8 wolverines occurred in the study area.

If we assume that this corrected occurrence rate equates to a probability of detection {given presence} = 1.0, then wolverine density varies with the area of influence of the baited stations (Figure 2). Our estimated wolverine density for this year ranges from 4.2 wolverine per 100 km^2 (if AOI = 1 km) to 0.26 wolverines per 100 km^2 (if AOI = 4 km). If we assume, as we did previously, that the AOI of baited stations was 2 km, then our estimate is 1.1 wolverines per 100 km^2, or 1 wolverine per 94 km^2.

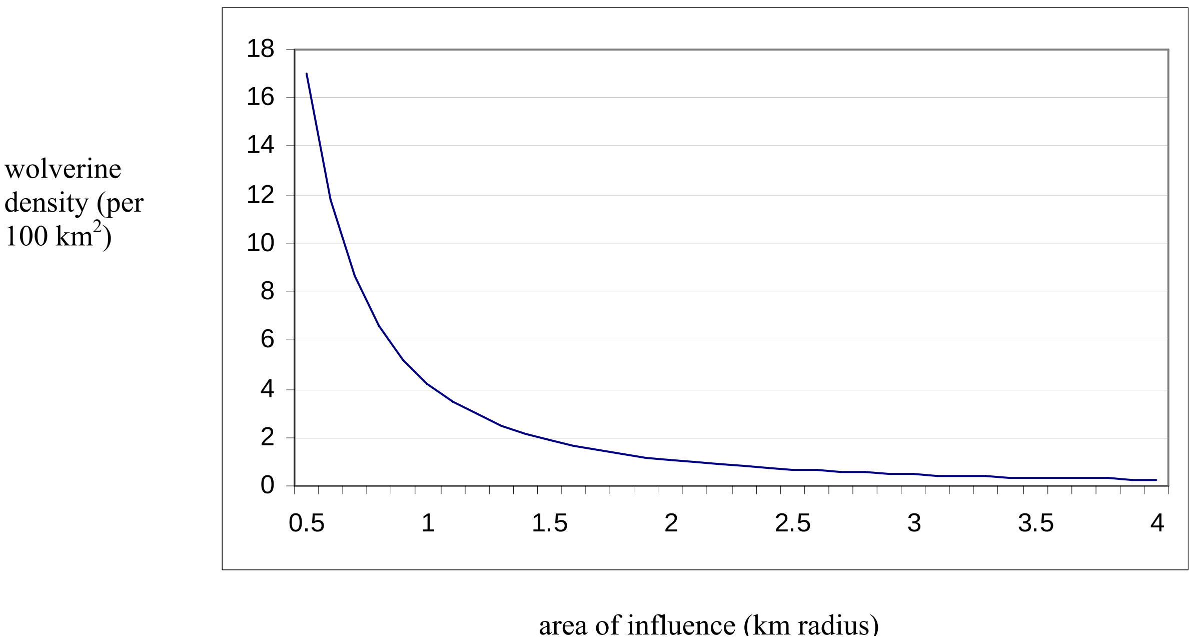

Figure 2 Estimated wolverine density in relation to area of influence of monitoring stations.

An estimate of 1 wolverine per 94 km^2 lays between estimates of 1 wolverine per 65 km^2 in Montana to the south (Hornocker and Hash 1981) and 1 wolverine per 177 km^2 in the Yukon to the north (Banci and Harestad 1990). A concurrent study of wolverine home ranges in Glacier National Park, Montana, produced a preliminary home range size estimate of 132 km^2 (Copeland *et al.* 2003).

This estimate is base on a number of positively identified individuals corrected with a seemingly reliable correction factor. However, without some estimate of the AOI of monitoring stations, there is considerable variation surrounding this density estimate. The AOI of monitoring stations can only be achieved through radio- or GPS-tracking of individuals within the study area; until this occurs, density estimates will continue to possess a burdensome amount of variance. The detection rate achieved in this study is still of utility, however, when used in a long-term monitoring program. This program requires estimates of adequate sample size and potential power to detect set changes in population size.

Statistical Requirements of a Wolverine Monitoring Program

The primary purpose of a wolverine monitoring program is to detect population changes, to provide wildlife biologists and land managers with long-term trend information that will guide active adaptive management efforts. A wolverine monitoring program must be statistically rigorous enough to distinguish real change from random variation, while being sensitive enough to detect change when it actually occurs (Gibbs *et al.* 1998). These demands are further complicated when the subject of the monitoring program is a rare, elusive, vagile species (Green and Young 1993); pilot data suggest this is indeed the case for wolverines.

Gibbs (1995) suggests that the power of a monitoring program to detect population change is dictated by 1) sample size of sites monitored; 2) count variation; 3) number of counts per plot; 4) plot weighting; 5) duration of monitoring; 6) interval of monitoring; 7) significance level assigned; and 8) the magnitude and direction of population trends. Although a full analysis of these requirements as they pertain to a Provincial-level wolverine monitoring program is reserved for the final phase of this project in 2004-2005, it is worth providing some preliminary discussion of a few of these parameters.

Sampling regime

Presence-absence studies often have low power to detect changes in species abundance. Strayer (1999) modelled the statistical power of presence-absence surveys to detect a change in animal abundance, using encounter rates as a proxy for population density, over a range of sampling regimes. It was found that spatially heterogeneous changes to populations were more reliably detected than uniformly distributed changes. More notably, all else being equal, power to detect population changes increased dramatically with number of points surveyed. This was especially true when encounter rates were low (as they are for wolverine). Based on his models, and our results obtained thus far, sample sizes, session lengths, and number of sessions need to be substantial to detect wolverine population change. When we acquire final data next year (2005-2006), we will use the program *Monitor* (Gibbs 1995) to delineate the sample sizes and power required to detect changes in wolverine populations through time.

Count variation

Most of the monitoring program parameters listed previously can be manipulated, with the exception of count variation. This parameter is measured as the coefficient of variation (CV):

$$CV = \frac{\text{mean (standard deviation)}}{\text{mean (mean density)}}$$

The density estimates (or average abundance, or equivalent value) and associated standard deviations taken from several different studies, or from pilot data, yield the coefficient of variation (Gibbs *et. al* 1998). Replicated data from 2004-5 and 2005-6 will be used to calculate the CV of wolverine density.

Although the CV is inherent in the species or system being monitored, it is influenced by species- or system-specific characteristics with associated variance structures that may be minimised through experimental design. Minimising the unexplained component of the variance structure will increase statistical power of a test. This may be done spatially and temporally (Schieck 2002).

Spatial variability can be minimised through *a priori* stratification of the landscape, and restriction of sampling effort to sites with similar habitat, topography, and disturbance types. Variability can also be minimised via *post hoc* blocking of the sites into some ‘treatment’ effects, such as ecoregion or habitat. We attempted to do this by deploying sites within a single ecoregion (the Foothills) and by restricting sampling effort to upland forests in areas of high topography relative to the adjacent landscape. Within this stratification, there still existed considerable variability in topography and habitat, especially when quantifying the surrounding area at landscape scales.

The temporal component of variability is much more difficult to minimise, or compensate for, especially for vagile organisms. If there is a wolverine in a given area, what is the probability we will detect it? The answer is based on:

1. Probability of encounter, p(enc): the probability that an animal will occur at the monitoring site within the sample period.
2. Probability of detection, p(det): the probability that given that an animal is present, that presence will be recorded.

To calculate our preliminary wolverine density estimate, we integrated temporal variability across an entire season, and assumed that the resultant probabilities of encounter and detection were equal to 1.0. This is almost certainly an erroneous assumption, although an unavoidable one in the face of a paucity of data. The calculation (or estimation) of these probabilities is critical to the assessment of statistical power of a monitoring program; there are a number of ways this can be accomplished for wolverines.

Probability of detection

In a presence-absence experiment, non-detection of a species does not necessarily imply that the animal is absent. However, a fundamental assumption of such an experiment, including monitoring programs, is that non-detections indicate an absence, and there is a zero probability of committing a Type II error by recording an animal as absent that is actually present. However, for vagile wide-ranging animals with large home ranges, this assumption is rarely fulfilled. Detection rates are often less than 1, and 'absences' can thus be mistranslated.

The last few years of data suggest that hair trapping undersamples species occurring at a site, thus providing a probability of detection that is consistently less than 1.0. Remote camera systems appear to be effective at detecting tree-climbing mustelids in Alberta, as they have in a variety of other species-studies and ecosystems (Carter and Slater 1991; Kucera and Barrett 1993; Mace *et al.* 1994; Wilton *et al*. 1994; Karanth 1995; Hernandez *et al.* 1997), and in this case provide a reliable detectability correction factor that allows us to approach a probability of detection of 1.0.

Probability of encounter

Mackenzie *et al.* (2002) provided equations for an estimation function for site occupancy rates when detection probabilities are less than 1. This maximum likelihood estimation function is based on probability of encounter, probability of presence, the aforementioned sampling parameters, and can include environmental or temporal covariates (Mackenzie *et al.* 2002).

Although useful in providing rigorous estimates of site occupancy, this equation still requires values for probability of encounter. As such values can rarely be accurately measured, an estimate of p(enc) is required – thus leading to an estimate based on another estimate.

To estimate the probability of encounter, it may be advisable to adopt a simplistic approach based on random movement models. For a vagile organism, the probability that any particular point in space is occupied at any given point in time (in this case, day) is defined as:

$$p(\text{occupation}) = \frac{\text{mean movement rate (km}^2\text{/ day)}}{\text{home range size (km}^2\text{)}}$$

By way of simple example, if a wolverine's home range is 100 km^2, and the mean movement rate is 1 km^2 / day, then the p(occupation) for any point within that home range on any given day is 0.01. The probability of encounter at a monitoring station is then a function of p(occupation), sampling period, and sampling replication within a target animal's home range:

$$p(\text{encounter}) \sim p(\text{occupation}) * \text{sampling period} * \text{replication within home range}$$

Continuing our example, if the probability of occupation for our species is 0.01, and we sample once within an individual's home range for 100 days, then our estimate of the probability of encounter approaches 1. It again becomes clear that to sufficiently minimise temporal variability in a long-term population trend monitoring program, there is a requirement for some basic GPS-collar study data on wolverines in Alberta: mean home range size, mean daily movement rates, and distribution (density) of home ranges. Without these data, our estimates of density, population size, and population trend, will be based on untested assumptions.

Estimating power to detect wolverine population trends

The ultimate objective of a monitoring program is to determine trends in population size. Strayer (1999) found that the statistical power of presence-absence surveys to detect population declines of <20% - 50% was very low. Strayer (1999) used encounter rate as a surrogate for population density, and found that power decreased as encounter rate logarithmically decreased; thus detecting changes in populations of sparse, rare species is more difficult than in more ubiquitous species. Power increased with sample size, but then reached a plateau. Power was greater if population distribution was not spatially variable; in general, surveys had more power to detect population declines when they occurred heterogeneously across the sampling area (*i.e.*, as local extinctions), rather than uniformly. However, this power dropped disproportionately faster than in uniform population declines, when species were rare and spatially variable, encounter rates were low, and sample sizes were small (Strayer 1999).

Thus, for wolverine - which are rare, have low expected encounter rates, have highly variable distribution in space and time, and are vagile enough to limit local extinctions - the construction of a statistically powerful monitoring program poses an extremely daunting challenge. Success will require very large sample sizes, which are costly to implement and logistically difficult. The minimisation of variability through sampling design is also essential; this pilot monitoring project will provide information to minimize some variability, but GPS or radiocollaring tracking data is required. Even with large sample sizes and a rigorous design based on sound estimates of monitoring parameters, it may be possible to reliably detect only very large population declines – not a desirable objective for a population already occurring in low densities, and with low recruitment rates.

Using Noninvasive Genetic Tagging Data in Habitat Selection Models

Although noninvasive genetic tagging has some potential pitfalls, controlled methods for analysis and appropriate interpretation of results can overcome them to provide useful information (Taberlet *et al.* 1999; Mills *et al.* 2000; Waits and Leberg 2000). The use of genetic information for landscape-level analysis of population connectivity and gene flow – a field known as 'landscape genetics' (Manel *et al.* 2003) - is gaining widespread acceptance. Noninvasive genetic data can ascertain the identity of species and individuals, allowing for estimates of population size (Foran *et al.* 1997; Woods *et al.* 1999; Mowat and Strobeck 2000; Popplewell *et al.* 2003; but see Boulanger and McLellan 2001). When presence or abundance data are combined with habitat and landscape data, resource selection functions (*cf.* Boyce *et al.* 2002) or other analyses can be calculated to determine habitat selection. Landscape analysis can be used to determine relationships between anthropogenic alteration of habitat and wolverine site occupancy. This information can in turn be used to create landscape models to aid in management, as has been done for wolverines in the northwestern United States (Rowland *et al.* 2003).

The wide variety of uses for noninvasive genetic tagging information for wolverines, beyond population monitoring, suggest that this is a worthwhile endeavor worth continuing, in light of our lack of information on wolverines and the expense associated with obtaining information. With an increased sample size of wolverines obtained from 2005-2006 monitoring, a habitat selection model will be created to predict wolverine occurrence in relation to stand type, anthropogenic footprint, and other habitat features.

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APPENDIX 1: PHOTOGRAPHS FROM TRAILMASTER™ CAMERA TRAPS.

Plate 1. Cougar (*Puma concolor*), Forestry Trunk Road northeast of Grande Cache.

Plate 2. Wolverine (*Gulo gulo)*, Forestry Trunk Road, northeast of Grande Cache, taken in 2004.