East Slopes Predators:

Mammalian spatial distribution and habitat selection in a heterogeneous mountain landscape.

Year-End Report 2011-2012

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ACKNOWLEDGMENTS

The East Slopes Predators Project was a joint partnership of several organisations. The Government of Alberta (Parks Division) provided majority funding for the project as well as in-kind capital and staff support. Alberta Innovates – Technology Futures (AITF) provided partner funding and capital in-kind support. The Government of Alberta (Fish and Wildlife Division) provided helicopter and staff support. The Western Transportation Institute (Montana State University) and Parks Canada provided staff and logistical support, as well as data sharing. Additional funding was provided by the University of Victoria (School of Environmental Studies), and the Yellowstone to Yukon Conservation Initiative (Sarah Baker Memorial Fund). The project is led by a Science Team that guided its development and completion:

Dr. Jason T. Fisher	AITF, U. Victoria	Principle Investigator, student supervisor
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Dr. Mark Edwards	Royal AB. Museum	Advisor, public communications
Dr. John P. Volpe	U. Victoria	Grad student co-supervisor

We offer a special thanks to those that participated in the strenuous field efforts:

Alberta Parks
Melanie Percy
Alex Macivor
Tom Partello
Véronique Demers
Amit Dutta
Rod Gow
Randi Axani
Randy Ramsden
Burke Duncan

Alberta Fish and Wildlife
Carrie Nugent
Jay Honeyman
Saundi Norris

Thanks too to Gord Klassen, Reuben Wiebe, and Evan McLean for the ever-important beaver baits. Thanks to Michelle Hiltz (AITF) for reviewing this Report. Finally, our sincere gratitude to Scott Jevons, Alberta Parks, for his exceptional GIS contributions.

Contents

PREFACE TO THE YEAR-END REPORT

This interim report highlights the field work conducted for the East Slopes Predators project in the winter of 2011-2012. The analysis of these data will be conducted in the summer and fall of 2012, in addition to ongoing data collection. The final conclusions of the project will be available in March 2013.

PROJECT SUMMARY

Alberta's East Slopes are a unique mosaic of protected areas, oil and gas development, recreational activity, forestry, and grazing land. The Slopes are also home to a diverse predator community, including grizzly and black bears, wolves, cougars, and wolverines, among others. Although the Rocky Mountains anchor predator populations, some species are known (grizzlies) or suspected (wolverines) to be declining. Oil and gas activity is often cited as a primary stressor on predator populations, but combined landscape footprints from multiple human activities, including recreation and road access, likely have cumulative effects on predators. The relative contribution of each of these sectors is controversial, and need to be discerned to allow effective management. Therefore, research that investigates how different human activities and footprints affect landscape-scale predator occurrence will inform long-term conservation of predator communities. To meet this goal, we are surveying predator occurrence (grizzly bear, black bear, wolverine, fisher, lynx, cougar, wolf, *etc.*) on the East Slopes using non-invasive detection methods, with a more in-depth focus on wolverine genetics. We will model the occurrence of predators in relation to natural habitat features and landscape alteration *via* (1) commercial forestry; (2) oil and gas development, including seismic line density; (3) recreational activity, including off-road vehicle routes; (4) livestock grazing and other agriculture; and (5) roads. We will examine the relative contribution of each landscape activity in explaining predator occurrence, and identify key stressors for each species, to inform management of landscape development that will allow effective carnivore conservation.

INTRODUCTION

Mammalian carnivores have decreased in abundance and range across North America since European colonisation, creating conservation concerns on a continental scale (Weaver *et al.* 1996; Laliberte and Ripple 2004). Habitat loss and fragmentation is a primary cause of many species' declines, and remains a pervasive anthropogenic phenomenon affecting ecological systems (Fahrig 1997, 2003). Large mammals, including carnivores and ungulates, may be particularly susceptible to landscape development; they require large population sizes to maintain long-term viability (Reed *et al.* 2003; Traill *et al.* 2010), and they integrate habitat disturbance over large spatial scales (Fisher *et al.* 2011).

Large mammals are also key components of Rocky Mountain biodiversity, and are thus of conservation concern. Mountains are unique landscapes with rare species and high biodiversity (Körner 2004; Molau 2004). Mountains act as barriers, isolating summit "fragments" from one another (Brown 1974). Conversely, mountain valley bottoms act as corridors by connecting distant habitats across regions (Carroll *et al.* 2001). Rugged topography with marked elevation differences across mountain ranges compress climate zones into small areas; variable slope, aspect, and microclimate create highly heterogeneous habitats, to which a diversity of species are adapted. Protecting mountain landscapes is crucial to conserving regional, and global, biodiversity (Körner 2004).

Protected areas may be critical to conserving rare species and other elements of biodiversity in landscapes where extensive anthropogenic landscape development is occurring outside park boundaries (Mittermeier *et al.* 2003; Rodriguez *et al.* 2004). Protected areas can provide refuge habitats and source populations for species that are otherwise impacted by development in the adjacent working landscape. Knowledge of the species and communities that occur within protected areas, and understanding how these relate to habitats and habitat disturbance, is essential for biodiversity conservation at landscape scales (Parrish *et al.* 2003; Zipkin *et al.* 2010).

Determining how a species' spatial distribution relates to landscape-scale habitat change (*e.g.* Wiens *et al.* 1993) is a vital requirement for landscape-scale conservation. Our research fills this need for predators (and ungulates) along a gradient of anthropogenic land-use on the East Slopes of the Rocky Mountains in Alberta, Canada.

Alberta's Eastern Slopes are a unique mosaic of protected areas, oil and gas development, recreational activity, forestry, and grazing land. They are also home to a unique group of predators, including grizzly and black bears, wolves, and wolverines, among others. Kananaskis Country, one of Alberta's Protected Parks and part of the Yellowstone to Yukon Conservation Initiative (http://y2y.net/) sits in the eastern mountain corridor that may be crucial to maintaining wolverines in Alberta (Fisher *et al.* 2009). Although the Rocky Mountains anchor predator populations, some species are known (grizzlies) or suspected (wolverines) to be declining, for reasons poorly understood. Furthermore, although Alberta's Rocky Mountains are covered extensively by protected areas, each has varying degrees of protection. The Rocky Mountain National Parks allow extensive recreation and are bisected by major transportation corridors, whereas adjacent Provincial Parks allow recreation as well as some industrial activity such as mining and forest harvesting. Although oil and gas activity is cited as a primary stressor on predator populations in Rocky Mountain Front Range landscapes (*e.g.* Fisher *et al.* 2009, 2012), other anthropogenic activities likely have cumulative effects that perhaps eclipse industrial development.

Correlations between animal occurrence and land-use are an important first step in generating hypotheses about the impact of fragmentation on species, but more in-depth analysis is needed to examine potential mechanisms. For example, some mammalian species are known to be negatively correlated with landscape development, but are these less-dense populations contiguous, or relatively disjunct, from adjacent dense populations in protected areas? We ask this question for one mammalian species in this mountain landscape – the wolverine, *Gulo gulo*.

Wolverines have been extirpated from most of the contiguous United States and much of eastern Canada (Laliberte and Ripple 2004; Aubry *et al.* 2007). Wolverine reproductive rates are driven by winter availability of ungulates (Persson 2005), though wolverines also prey on caribou neonates (Gustine *et al.* 2006) and other mammals. Human-caused wolverine mortality is typically additive to natural mortality, often causing population declines (Krebs *et al.* 2004; Lofroth and Ott 2007). Trapping and road mortality alone accounted for 46% of known-cause wolverine mortalities across several wolverine studies (Krebs *et al.* 2004). Wolverines are sensitive to landscape development (Laliberte and Ripple 2004; Aubry *et al.* 2007) and avoid human-disturbed areas (Carroll *et al.* 2001, Rowland *et al.* 2003, May *et al.* 2006), such as timber-harvested clear-cuts (Hornocker and Hash 1981). In B.C., wolverines selected against habitat impacted by recreational activities (Krebs *et al.* 2007). In west-central Alberta, wolverine occurrence is negatively related to seismic line density (Fisher *et al.* 2009, Fisher *et al. in review*), but the effect of landscape development on wolverines' spatial ecology and gene flow is also unknown.

To fill this gap, we are examining wolverine density, habitat selection, and landscape genetics in this multi-use mountain landscape. We are surveying the spatial distribution of wolverines and other predators, using statistical models to estimate wolverine densities and gene flow across this region, and creating habitat selection models that will predict where predators do and do not occur in relation to natural mountain heterogeneity and landscape development.

METHODS

Theory: Landscape-scale surveys of mammalian occurrence

Many large mammals - despite their size - are rare and elusive, making occurrence data difficult to obtain. Overcoming this hurdle requires development of survey methods that allow reliable species detection (McDonald 2004; Long *et al.* 2008). We are using a combination hair capture with non-invasive genetic tagging (NGT) and camera trapping that has proved effective for a spectrum of mammals in mountain environments (Fisher *et al.* 2009, 2011, 2012). NGT through hair trapping is fast becoming a popular tool for surveying mammals (Waits 2004; Kendall and McKelvey 2008), including rare and elusive ones such as wolverines (*e.g.* Flagstad *et al.* 2004; Mulders *et al.* 2007; Hedmark and Ellegren 2007; Fisher *et al.* 2009, 2011; Magoun *et al.* 2011). Hairs captured noninvasively can be identified to species and to individual using DNA microsatellite analysis (McKelvey and Schwartz 2004a,b). Species' encounter histories derived from NGT data can inform abundance estimates (Mowat and Strobeck 2000; Mowat and Paetkau 2002) and can be used in conjunction with habitat data in resource selection functions (Manly *et al.* 2002) to determine how species occurrence relates spatially to habitat loss. With additional genetic analysis, hairs can be identified to individual and gender for abundance estimation (Fisher *et al.* 2009), and to estimate gene flow in relation to landscape features (Schwartz *et al.* 2009). NGT provides unique information but is, by itself, not a wholly reliable estimator of occurrence and density. When a species' hair is not detected at a site, it is unknown whether

it is truly absent from a site, or present but undetected (MacKenzie *et al.* 2002, 2006; MacKenzie 2005). Accurately sampling a species' occurrence at a site depends on the species' presence at time of sampling, and the ability of the sampling method to detect that animal when present. This bias can be corrected using a multi-method approach to surveying, including NGT and infra-red remote cameras (IRCs; Balme *et al.* 2009; O'Connell *et al.* 2006, 2010). Further, we can use statistical techniques to estimate and correct for imperfect detection. MacKenzie *et al.* (2002, 2006) illustrated that species probability of occupancy at a site (ψ) must be modelled in conjunction with its probability of detection (p): the probability of detecting that species when it is, in fact, present. Estimating p provides key information to more accurately estimate species occupancy at sites across a study landscape.

Study Area

Predator occurrence and distribution were sampled in the central Rocky Mountains of Alberta, Canada, part of the Western Cordilleran system (Figure 1). Topography is rugged, with high peaks, steep-sloped ridges, and valley bottoms. Coniferous forest 80-120 years old (*Pinus contorta, Picea glauca, Picea mariana*, and *Abies balsamea*) dominate this landscape, with some small deciduous stands occurring throughout. Small stands of black spruce and mosses (*Sphagnum* spp) occurred in low-lying areas. Pine and mixed stands were often fairly open. Younger fire- or harvest-origin stands were embedded within this matrix, as well as deforested linear features (seismic lines) of varying densities and stages of regeneration resulting from oil exploration. Recreational trails, roads, and mines all occur in this landscape. The majority of this region sits within Alberta's protected areas network, a series of areas with varying degrees of protection and intensity of land-use, collectively termed Kananaskis Country.

In addition, we are pooling data collected in Banff and Yoho National Parks through a partnership with Tony Clevenger (WTI-Montana State University) and Mike Schwartz (U. Montana). This region was sampled in 2010-2011 and we are adding wolverine genetic data sampled in *East Slopes Predators* to theirs, to answer questions about east-west gene flow from the National Parks into more heavily impacted areas on Parks' eastern boundaries.

Experimental Design and Sampling

We surveyed predator occurrence using a systematic design consisting of 12-km x 12-km grid cells, plotted on the landscape using ARCGIS (ArcGis 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA). Within each cell, we placed a survey site generally mid-elevation, in drainages or other travel corridors, at sites with escape cover and evidence of animal movement (Figure 1). Subjectivity at the site level serves to maximise probability of detection, but does not affect our probabilistic design, since statistical inference will occur at the scale of the grid-cell.

NGT *via* hair sampling was conducted by wrapping Gaucho® barbed wire (Bekaert, Brussels, Belgium) around a tree baited with whole beaver; individuals would climb the tree for the bait, and leave a hair sample. Hair traps were deployed at all sample sites and we collected hair samples monthly. DNA from hairs was analysed by Michael Schwartz's lab at the USFS using established techniques (Schwartz *et al.* 2009) to identify species of mammals detected. We also deployed a Reconyx RM30 or PM30 infrared-triggered digital cameras (Reconyx, Holmen, Wisconsin, USA) at each sampling site, set so that the camera imaged the hair trap.

We set carcass-baited sampling sites in December and monitored them monthly until March, during which time food was scarce and thus species detection most likely. A total of 27 cells were sampled in 2010-2011, and 43 cells were sampled in 2011-2012. Three cells have two sites, where the trap and camera had to be moved (Jan 2011) to avoid human activity.

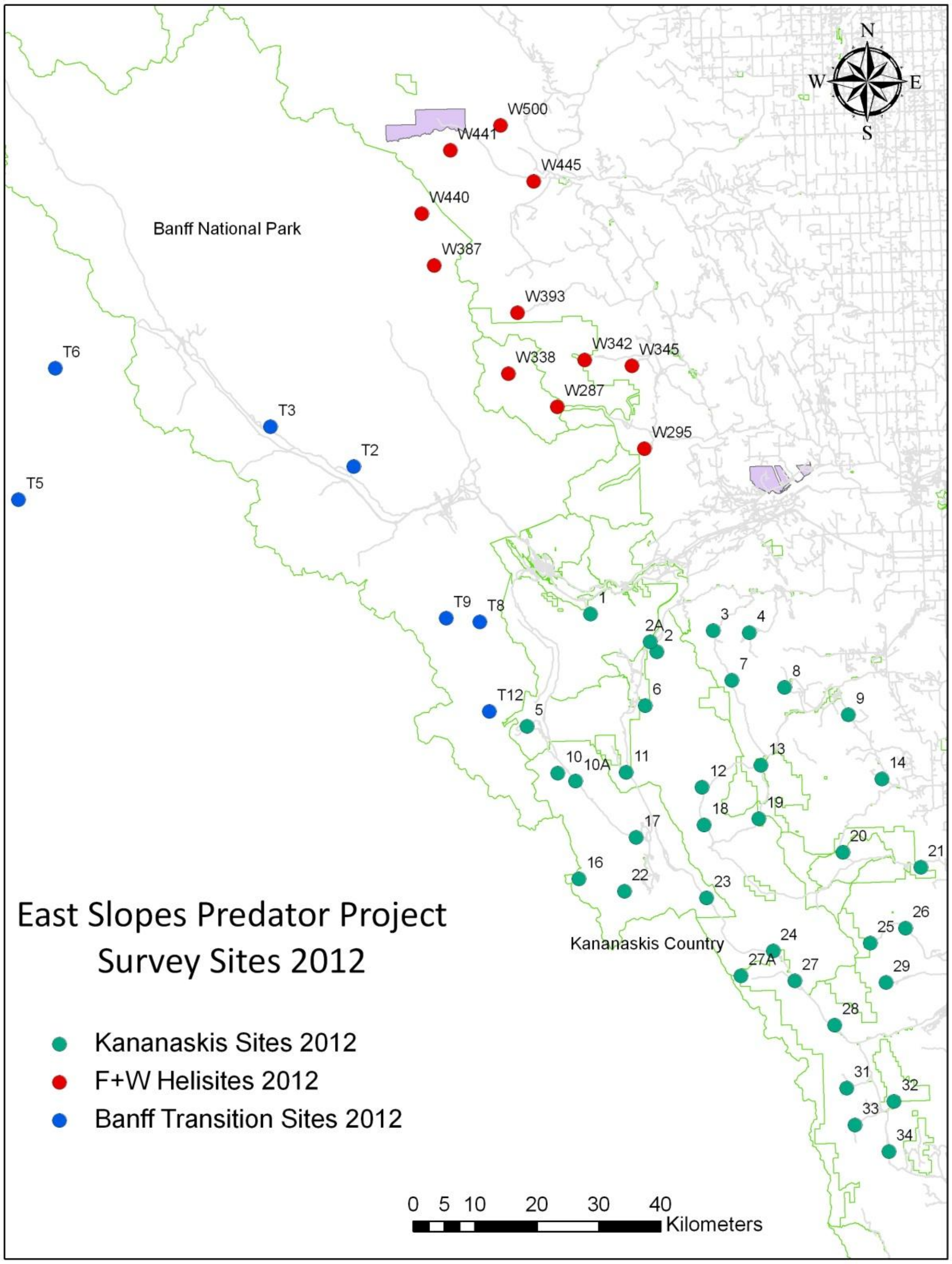


Figure 1. Predators are being sampled at 43 cells in Kananaskis Country and environs by ground (in teal) and helicopter (in red). Additional sites (in blue) are being added by WTI / Parks Canada to the 47 sites sampled in Banff, Kootenay and Yoho National Parks.

RESULTS

2010-2011 Wolverines

A total of 197 hair samples were collected from 27 sites in 2010-2011: cells 1-14, and 17-29. These were analyzed for species identification using mitochondrial DNA. Of these, enough DNA for species identification was obtained from 122 of the samples (62%). Fifteen of these hair samples were from wolverine, from 6 different sites. Other species identified from these samples include marten (*Martes americana*), bobcat (*Lynx rufus*), lynx (*Lynx canadensis*), coyote (*Canis latrans*), northern flying squirrel (*Glaucomys sabrinus*), deer (*Odocoileus sp*.), moose (*Alces alces*) and cow (*Bos taurus*) (Appendix 1).

Wolverines were detected at 6 of 27 sites (22.2%). Only one site had multiple detections (site 23) at all three month-long surveys; the rest had single detections (sites 10A, 13, 21, 22, 24, and 27). We ran hierarchical models in Presence 4.1 (Hines 2006) to estimate occupancy and detectability. GIS analysis of habitat covariates is still in progress, so we ran single-season models without covariates to roughly estimate these parameters, to inform this report. These models assumed occupancy was constant among sites (in the absence of habitat covariates to partition out variance), and that detectability was constant, or varied through time, or differed among groups of sites (Table 1).

We found that *p* was constant throughout the winter. The evidence ratio (ER; Anderson 2008) of models including constant *p* was 3.5, and ER > 2 indicates significant support. Estimated *p* did not likely vary among groups; although this is the top model, total support for groups was not strong (ER = 0.73). The top-ranked single-group model estimated $p = 0.275$ (standard error = 0.151), and occupancy $\Psi = 0.3588$ (s.e. = 0.1891).

In summary, hair trapping had a ~ 28% chance of detecting wolverines given they were present. Hair was collected from 22% of sites, and we estimated that 36% of the sites of this study area were occupied by wolverines. Analysis of hair samples is ongoing in early 2012 to ascertain the number of unique individuals present.

Table 1. Hierarchical models of repeated wolverine hair sampling (monthly December 2010 – March 2011). Models assumed that probability of detection (*p*) was constant (.), varied among GROUPS, was SURVEY-SPECIFIC, or varied through time with a TREND.

Model	AIC	ΔAIC	AIC wgt	Model Likelihood	# parameters	.-2LL
2 groups, Constant *p*	53.69	0	0.4124	1	4	45.69
1 group, Constant *p*	53.93	0.24	0.3658	0.8869	2	49.93
ψ(.),*p*(trend)	55.67	1.98	0.1532	0.3716	3	49.67
1 group, Survey-specific *P*	57.58	3.89	0.059	0.143	4	49.58
2 groups, Survey-specific *P*	61.22	7.53	0.0096	0.0232	8	45.22

2010-2011 Predators

Bobcat (34 samples), marten (13 samples), and lynx (12 samples) were the other predator species most frequently detected *via* hair sampling. Lynx detections were too few (4 sites) to allow maximum likelihood estimators to achieve convergence. However, bobcat and marten detections were sufficiently dispersed to allow estimation of *p* and ψ. Bobcat detections were constant the whole winter and among sites (Table 2). Bobcats had a relatively high detectability (*p* = 0.44, s.e. = 0.165). Hairs were pulled from 5 sites (18%), and we estimated that 22% of sites were occupied by bobcats (ψ = 0.225, s.e. = 0.100).

Table 2. Hierarchical models of repeated bobcat hair sampling (monthly December – January). Models assumed that probability of detection (*p*) was constant (.), varied among GROUPS, was SURVEY-SPECIFIC, or varied through time with a TREND.

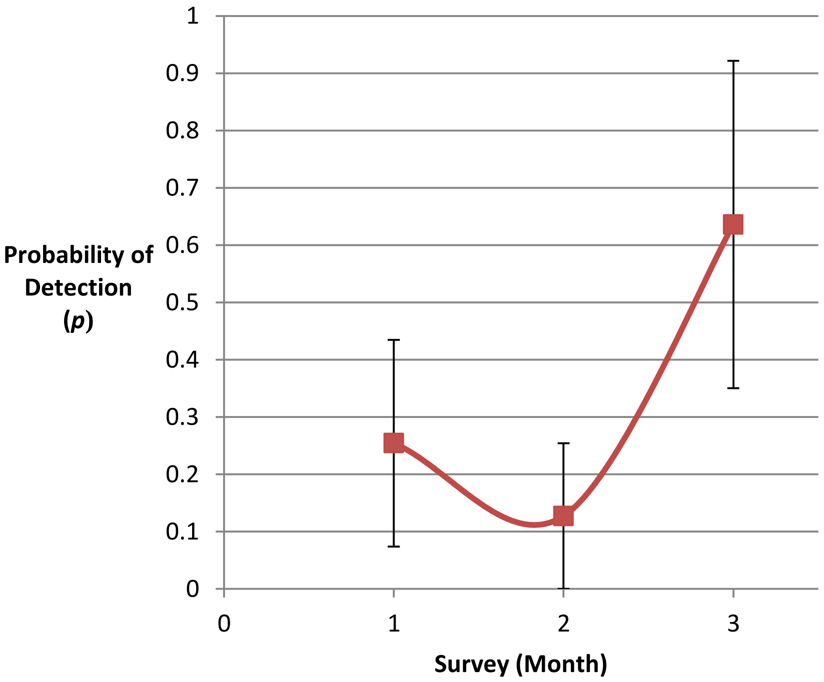
Model	AIC	ΔAIC	AIC wgt	Model Likelihood	# parameters	.-2LL
ψ(.),*p*(.)	49.20	0	0.6113	1	2	45.2
ψ(.),*p*(trend)	50.86	1.66	0.2666	0.436	3	44.86
ψ(.),*p*(survey)	52.74	3.54	0.1041	0.1703	4	44.74
2 groups, Constant *P*	56.81	7.61	0.0136	0.0223	4	48.81
2 groups, Survey-specific *P*	59.10	9.9	0.0043	0.0071	8	43.1

Marten detections may have varied among surveys, either independently among surveys (model 1) or as a trend through time (model 2), but the evidence for this variation is weak due to small sample sizes (Table 3). The top-ranked model suggests that there is a 13% - 64% chance that a site will detect marten given it is present (Figure 2). Marten hairs were collected from 6 sites (22%) and we estimated that 29% of sites were occupied by marten (ψ = 0.291, s.e. = 0.136).

Table 3. Hierarchical models of repeated marten hair sampling (monthly December – January). Models assumed that probability of detection (*p*) was constant (.), varied among GROUPS, was SURVEY-SPECIFIC, or varied through time with a TREND.

Model	AIC	ΔAIC	AIC wgt	Model Likelihood	# parameters	.-2LL
ψ(.),*p*(survey)	53.22	0	0.368	1	4	45.22
ψ(.),*p*(trend)	53.48	0.26	0.3232	0.8781	3	47.48
1 group, Constant *p*	53.93	0.71	0.258	0.7012	2	49.93
2 groups, Constant *p*	57.93	4.71	0.0349	0.0949	4	49.93
2 groups, Survey-specific *p*	59.51	6.29	0.0158	0.0431	8	43.51

Figure 2. Probability of detecting marten in Kananaskis Country varied among surveys in the top-ranked model, though support is not strong and estimates are imprecise due to small sample sizes.



2011-2012

Hair samples are still being collected for the 2011-2012 season, and will be sent be to M. Schwartz's lab for analysis thereafter. Thus far, we have 382 samples from 39 of the 43 sites: 91 in the first session, 165 in the second session, and 126 in the third and most recent session. Hair samples were clustered in space; 15 of these 39 sites provided only 1-3 hairs. Genetic analysis will be conducted in 2012 to determine what species were detected at these sites, and how frequently.

Likewise, camera data are still being collected, and will be analyzed once winter collection is completed and spring collection begins. So far, we have collected continuous camera data since November 28, 2011. Camera data have detected wolverine at 7 of the 43 sites (16.3%). To date, only two sites (sites 10A and 24) detected wolverines at >1 survey; the remaining sites have had single detections (sites 5, 16, 27A, 34, and W338). Due to snow accumulation, camera data has not detected wolverine at site 23 however fresh tracks of wolverine were evident at the site upon the last site revisit in March. In addition, sites 10A and 24 have detected wolverine across both sampling years (during the previous 2010-2011 and the current 2011-2012 sampling periods). Camera traps have also shown few of the detected wolverine to climb the tree and cross the barbed wire which may result in a decreased ability to identify individuals using DNA. During the recent winter sampling season, camera traps have been effective in detecting several other species including: American marten (*Martes americana*), lynx (*Lynx canadensis*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), grey wolf (*Canis lupis*), red fox (*Vulpes vulpes*), northern flying squirrel (*Glaucomys sabrinus*), golden eagle (*Aquila chrysaetos*), deer (*Odocoileus sp.*), and moose (*Alces alces*).

DISCUSSION

Research on wolverines and other predators conducted by Fisher *et al.* (2009, 2011, 2012) focused efforts along a gradient of human use from the Willmore Wilderness (rugged, low human use) to eastern slopes of the Rocky Mountains, in Alberta's Foothills (lower elevation, high human use). This study found significantly higher occupancy within the protected area of the Willmore Wilderness compared to markedly lower occupancy along the adjacent Foothills.

Wolverine occupancy in the East Slopes and in Banff National Park mirror the trend they observed. A preliminary examination of camera-trap data suggest that wolverine occupancy rates are higher in Banff National Park than along Alberta's East Slopes, that may mimic the gradient of wolverine detection rates found during the Willmore Wilderness and Foothills Wolverine studies. In Banff National Park during the winter of 2010-2011, naïve (unadjusted) occupancy by wolverines was 89%, compared to the lower detection rate found in a slightly smaller survey effort conducted during that same year in Kananaskis Country of only 25.8%. Our most recent sampling effort (winter of 2011-2012) in Kananaskis Country and environs was broadened to a study-area size that compares to the study area in Banff National Park, at ~600km^2. The increased study area from the 2010-2011 to 2011-2012 sampling periods along Alberta's Eastern Slopes was expected to increase our detection rate, rather our current data shows a similar detection rate.

In addition, 4 out of the 7 camera detections (57%) from 2011-2012 in Kananaskis Country showed wolverines climbing the tree and spending time at the baited sites, exhibiting a behavior similar to those observed in Willmore and Banff. In contrast the tentative and reluctant behavior observed by the other 43% may affect detectability using NGT and hair-trapping. Further analysis of the relationship between behavior and detectability is warranted.

Looking Ahead: Plans for 2012-2013

Once data have been collected, genetic data analysed, and Banff data have been pooled, we will proceed with the development of statistical models to (1) estimate wolverine densities and gene flow across this region, and (2) estimate habitat selection by predators in relation to natural habitat and human footprint. The results of these analyses will provide insight into the patterns of wolverine detection rates we have observed along this gradient from National Parks to Alberta's East Slopes, and will help explain where predators do and do not occur in relation to natural mountain heterogeneity and landscape development.

In addition, we will examine differences in wolverine behaviour at sampling sites from low-impact to high-impact areas, to try to discern some mechanisms for differences in detectability across landscapes. If behavioural differences are detected, this information can be used to test the effectiveness of hair traps in areas that we may predict cautious and tentative behaviour, and correct the probability of detecting individuals using standardized DNA sampling methods.

Finally, with additional support, we hope to deploy more cameras throughout Kananaskis Country in higher-elevation landscapes in locations that are inaccessible by road or foot during the winter months, to detect wolverine family groups. The opportunity to deploy multi-camera arrays will also allow us to analyze the effects of multiple detection methods on detectability, which may increase the precision of estimates of occurrence for a variety of mammal species. The sum of our conclusions will provide key information to managers for decision-making and land-use planning that will help ensure wolverines and other native predators will persist along Alberta's East Slopes.

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APPENDIX 1

Hair samples collected 2010-2011 by species, from January (survey 1) to March (survey 3), in Kananaskis Country, Alberta.

Site	Survey	Bobcat	Lynx	Cow	Coyote	Deer	Marten	Moose	Flying Squirrel	Wolverine	Beaver (bait)	Poor DNA
1	1						2					
1	2										1	2
1	3											2
2	2				1						2	1
2	3						3					1
3	1						1					1
3	3						1				1	
4	2						2					2
4	3						1				1	
5	1	1	4								2	2
5	2					1					2	3
6	1								2			2
6	2											
6	3											1
7	1								2			1
7	2								2		2	1
9	1			1								3
9	3										1	2
10	1										2	
10	2							1		2		1
10	3											2
11	1											1
11	2										1	1
11	3						2				2	5
12	3								1			1
13	3									1		
17	2											3

18	1		2								3	
18	2											2
18	3										2	
19	2										1	2
19	3											1
20	1										1	1
20	3	11										
21	2											1
22	1							1			3	1
22	2									2		1
22	3					1						
23	1		5							3	1	2
23	2									3		1
23	3					1				2		2
24	1									1	1	1
24	2											1
25	2	6										7
25	3	3										4
26	1	2										
26	2	2									1	3
26	3						1					1
27	1											2
27	2											2
27	3									1		
28	1	3	1									
28	2	6										1
28	3										2	1
29	3					2						