
# THE MORAINE MESOCARNIVORE PROJECT

## 2015-2016 REPORT
## Landowners and Volunteers

Frances Stewart, *M.Sc., Ph.D.* Candidate
University of Victoria
Dr. Jason T. Fisher, *Ph.D.*
Alberta Innovates

June 3, 2016

## Executive Summary

The *Moraine Mesocarnivores Project* (MMP) investigates how protected areas, private woodlots, and connectivity within the Cooking Lake Moraine (CLM) – a mixed-use landscape of protected areas and developed private land – affect mammalian diversity. Our goals are to (1) measure mammal diversity and statistically relate this to landscape structure, and (2) test for connectivity within and among protected areas by examining the movement and genetic structure of fisher (*Pekania [Martes] pennanti*) populations. In November 2013 we deployed 64 sampling points across in a systematic design and sampled mammal species occurrence using non-invasive genetic tagging *via* hair trapping, and camera trapping. In 2014-2015 we conducted genetic analysis on these hair samples. From November 2015 through March 2016, we repeated hair trapping and camera trapping, to investigate changes in species distribution through time. We also live-trapped and GPS-collared 14 fisher individuals under strict animal use guidelines. We are mapping their movement pathways in relation to natural and anthropogenic landcover, to understand how development facilitates (or impedes) their movement, and hence persistence.

We have collected 230,118 photos and 750 hair samples to date. Moose (*Alces alces*), white tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), wolf (*Canis lupus*), least (*Mustela nivalis*), short-tailed *(Mustela erminea*) and long-tailed weasels (*Mustela frenata*), porcupine (*Erethizon dorsatum)*, striped skunk (*Mephitis mephitis*), wood bison (*Bison bison athabascae*), plains bison (*B. bison bison*), elk (*Cervus canadensis*), black bears (*Ursus americanus*), cougar (*Puma concolor*), and domestic animals such as the domestic dog (*Canis lupis familiaris*) were also detected, illustrating that mammalian diversity is high across this landscape. Statistical analysis of diversity-habitat relationships will be conducted in 2016-2017, as well as final genetic analysis of newly collected fisher samples.

Fishers were detected *via* cameras at 45 of 64 sites checked (70% naïve occupancy); fishers are more widespread in the CLM than expected. On 2013-2014 samples we conducted mitochondrial and microsatellite (nuclear) DNA analysis and identified 16 fishers (6 males, 10 females). Statistical density estimates are underway. To date, neither

DNA line (mitochondrial or nuclear) show traces of reintroduced Ontario or Manitoba lineages; instead CLM fishers are related to fishers in the Alberta boreal and Rocky Mountains, indicating functional connectivity to the rest of the province despite a high degree of development surrounding the CLM.

The next fiscal year (2016-2017) will be dedicated to final data analysis, including genetic analysis of hair samples collected in 2016 to confirm and supplement our genetic results to date, as well as statistical analysis of camera-based mammal community data and GPS telemetry-based fisher movement data.

Please feel free to contact either myself (fstewart@uvic.ca), or Jason (Jason.fisher@albertainnovates.ca), at any point with questions about this research. You can also keep up to date on project results and happenings by visiting the project website: www.mesocarnivore.weebly.com. We very much appreciate your enthusiasm and support of this project to date, and we look forward to delivering ongoing results as this project comes to a close.

Best,

Frances

## Contents



## Acknowledgments

The majority funding for this project was provided by Alberta Innovates, Alberta Environment & Parks, and the Beaver Hills Initiative. Student funding was provided by NSERC IPS Scholarship and by the University of Victoria's School of Environmental Studies. Alberta Conservation Association and the Fur Institute of Canada provided additional funding. The Friends of Elk Island Society lent extensive volunteer support. Phillipe Thomas at Environment Canada provided Alberta boreal samples. Jeff Bowman at Ontario MNR and Dean Berenzanski from Manitoba provided fisher samples. Thanks to Ksenija Vujnovic, Dr. Joyce Gould, Tamara Zembal, Dr. Malcolm McAdie, Ian Brusselers, Dr. Brian Eaton, Sandra Melenka, Susan Allen, Brenda Dziwenka, Connie Jackson, and Michelle Lefebvre for assistance. Brenda Wispinki at Beaver Hills Initiative championed this project for future funding. Barry Robinson and Pinette Robinson at Parks Canada helped facilitate this research within Elk Island National Park. Thank you!

A project team led this research:

Dr. Jason T. Fisher, Senior Research Scientist, AI
Frances Stewart, PhD Candidate, University of Victoria
Drajs Vujnovic, Alberta Environment & Parks
Dr. Margo Pybus, Alberta Environment & Parks
Dr. Glynnis Hood, Assoc. Professor, Univ. Alberta – Augustana
Dr. John Volpe, Assoc. Professor, University of Victoria

## Introduction

Conserving biodiversity and ecological integrity is a primary purpose of parks and protected areas (PAs) worldwide, though there is great variability in how well PAs are achieving this goal[1]. In Alberta, Canada, the "working landscape" has been impacted by agriculture for over a century; forest harvesting for over fifty years; and more recently by rural residential development, and petroleum exploration and extraction. Each resource sector is accompanied by marked increased in road and trail access. The cumulative effects of multiple forms of development are widespread across Alberta, contributing to declines of woodland caribou[2,3], range contraction of wolverines[4], and a suite of other ecological impacts[5]. Growing landscape impacts necessitated a provincial strategy to plan for land-use with a goal of maintaining biodiversity - Alberta's Land-use Framework[1] (LUF). Protected areas are a key component of the LUF, which is designed to balance environmental sustainability with economic opportunity.

The LUF assumes that Alberta biodiversity will be maintained by a combination of PAs and the working landscape, functioning together to sustain viable wildlife populations and biotic communities. However, this assumption only holds if (1) PAs and adjacent patches of working landscape are functionally connected – operating together to support animal populations; and (2) large intact landscapes and PAs are functionally connected over large scales to allow immigration and emigration, and hence gene flow, among populations[6-9]. These assumptions have never been tested for Alberta, but are crucial to maintaining ecological integrity and biodiversity of a landscape.

The biodiversity value and conservation role of the many small protected areas common throughout Alberta – in addition to protected parcels owned by environmental groups – has always been controversial. Most small PAs are embedded within mixed-use landscapes – patchworks of forested, protected areas, small-scale agriculture, rural residential areas, and natural fragments on private land. How valuable are these PA islands for maintaining biodiversity and ecological integrity?

In fact, increasing evidence shows they can be extremely valuable, particularly when patches of natural habitats are connected with one another. It is true that habitat

---

[1] https://www.landuse.alberta.ca/Documents/LUF_Land-use_Framework_Report-2008-12.pdf

fragmentation and loss adversely affect the persistence of many wildlife species[10-12]. However, habitat fragmented is not always lost. Mixed forested and agricultural landscapes can support viable and persistent wildlife populations in woodland patches within agricultural landscapes[13-15], provided habitat patches remain sufficiently connected for wildlife species[16]. In fact, agricultural habitat may actually provide complementary or supplementary resources to species living in wooded patches (*i.e.*, prey), facilitating their persistence[6,17]. Just as importantly, emerging research shows that protected areas can act as catalysts for integrated conservation between government and private lands in mixed-use landscapes[18]. Both ecologically and socially, small protected areas may be significant, even essential, in maintaining biodiversity in mixed-use landscapes.

Measuring all biodiversity is a daunting task but mammals are a useful biodiversity indicator. Mixed-use landscapes may be particularly suited to mammalian mesocarnivores – mid-sized mammalian predators, such as marten, fishers, foxes, coyotes, lynx, and raccoons – which may persist in forest landscapes with a degree of agricultural incursion or fragmentation. Working landscapes often have reduced or absent top predator populations (such as bears and wolves). In the absence of top predators, mesocarnivores are released from predation and competition, and their populations can increase[19,20]. Moreover, fragmented landscapes often support diverse small-mammal populations, which provide abundant prey for mesocarnivores. Where wooded patches are large enough to provide breeding habitat, but are interspersed with "novel" agricultural patches that provide a resource subsidy, fragmented forest landscapes may support persistent populations of mesocarnivores. The landscape features allowing species' persistence is both landscape and species-specific[21], preventing generalities from other parts of the continent. In western Canadian landscapes, we know little about mesocarnivore species persistence in fragmented, mixed-use forest-agricultural systems, but this information is vital to evidence-based decision-making designed to maintain ecological integrity within small protected areas.

We seek to help supply this information by examining the diversity, distribution, and connectivity of mesocarnivores on the Cooking Lake Moraine in central Alberta: a matrix of protected areas, private land with natural habitats, and areas of significant anthropogenic disturbance. We ask several related questions:

1. What mesocarnivore species occupy this mixed natural-agricultural system?
2. What landscape elements – including natural and anthropogenic features – positively or negatively affect mammal occurrence and diversity?
3. How functionally connected are PAs within this landscape? Can animals move among disjunct PAs to form functional home ranges?
4. How functionally connected is the CLM to other forested landscapes to the west and north, separated by intensive development? Specifically, are fishers (*Pekania pennanti*) occurring on the Moraine more genetically related to re-introduced ancestors from Ontario and Manitoba, or is there evidence of genetic contribution from adjacent landscapes indicating functional connectivity?

# Methods

## Study Area

The Cooking Lake Moraine is approximately 1,500 $km^2$ of primarily aspen forest with patches of white spruce, open meadows, and small permanent water bodies (Pybus *et al.* 2009; Patriquin 2014). This (relatively) intact and heterogeneous complex sits in a matrix of agricultural land. Our study area covers the moraine and its agricultural environs, an area over 1,060 $km^2$ in size. The moraine is, to a large degree, spatially disjunct from tracts of contiguous forests to the north and west. Several parks and protected areas cover this landscape, limiting development and human activity (Figure 1). As such, the CLM may be an important source of biodiversity for the entire region. Elk Island National Park, within the moraine, is a fenced park with large populations of ungulates, wolves, coyotes and other mesocarnivores, as well as diverse bird and plant communities. This Park, together with the many provincial protected areas and conservation properties (*i.e.*, ACA, DU, ABFG, EALT and NCC) on the moraine, support high biodiversity, but an empirical, multi-species analysis of the composition of the mammalian community has not been conducted.

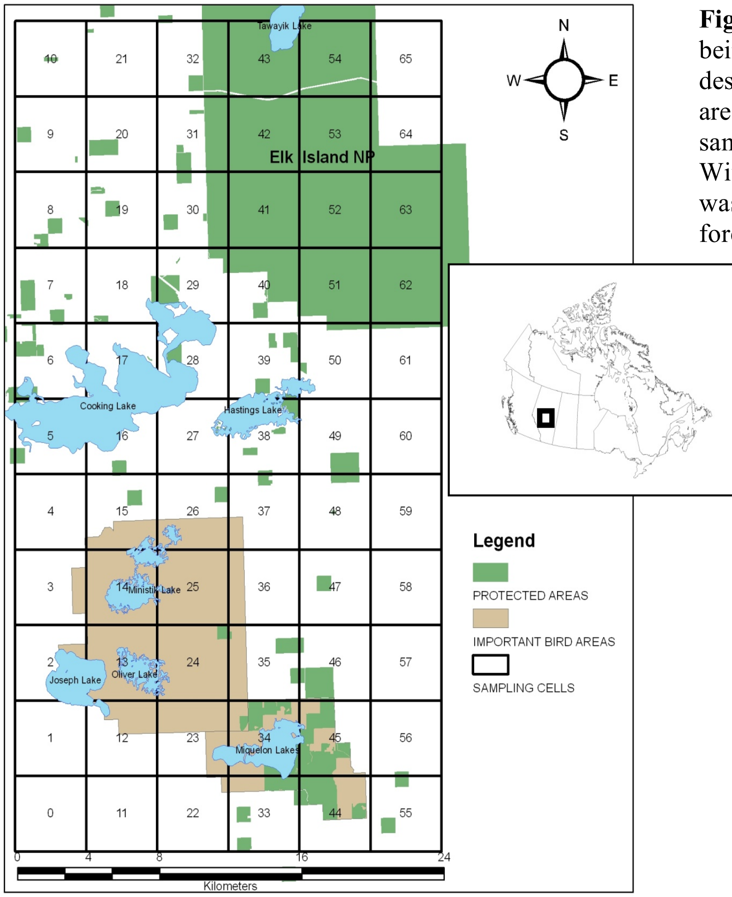


**Figure 1.** Mesocarnivore diversity is being sampled within a systematic design on the Cooking Lake Moraine area of Alberta, Canada. 66, 4km x 4km sampling cells were designated in GIS. Within 64 of these cells, a sampling site was subjectively placed within a forested area a minimum of 1-ha in size.

## Species sampling

Mesocarnivore occurrence is being surveyed using a multi-method approach[22] involving a combination of non-invasive genetic tagging (NGT)[23] *via* hair sampling and infra-red remote cameras (IRCs)[24]. This double-method sampling has proven effective for mammals elsewhere in Alberta[4,25,26] and has a high probability of detecting mesocarnivores, including fishers [27].

Hair samples for NGT were collected using Gaucho barbed wire wrapped around a tree baited with beaver fat and O'Gorman's scent lure. At each station, we also deployed one Reconyx™ infrared-triggered digital camera. Cameras are placed *ca.* 6-10 metres from the tree such that the camera's detection cone and field of view includes the NGT hair trap and the area surrounding it (Figure 2).

DNA from collected hairs have been extracted and analysed to identify species using mitochondrial DNA (mtDNA), which is then compared against a DNA reference library of all known mammal species in the region. For fishers, individuals and gender are identified using microsatellite (nuclear DNA) analysis. Individual capture histories can be used in mark-recapture models to estimate population sizes and densities.

Relatedness to fisher populations from the Alberta boreal forest, Rocky Mountains, and Ontario and Manitoba is being assessed using the program STRUCTURE, which compares microsatellite markers. Frances Stewart (University of Victoria) will use the same samples to conduct a mitochondrial genetic analysis to further explore relatedness.

NGT provides unique information, but may underestimate species' occurrence. Absence of hair may result from (1) an absent individual, or (2) a present, but undetected individual. Such imperfect detection has ramifications for estimates of species occupancy, density, and habitat use[28,29]. To maximise detectability, we are surveying mesocarnivore occurrence using camera traps and hair traps. Cameras are triggered by heat-in-motion and are set to take a series of 5 photographs at each detection event. Images containing human activity are permanently deleted immediately; following this, all other images are being triple-redundant stored for analysis. Images are analysed and summarised for species presence, creating a serial detection-nondetection dataset for each site. Camera data on the mesocarnivore community will inform landscape-scale species-distribution models.

Finally, in 2016 we captured and collared fourteen adult fishers across the Cooking Lake moraine from Miquelon to Elk Island National Park, to understand how animals use multiple protected and anthropogenic patch types in this landscape. Animals were fitted with an *e-obs* GPS collar that stores location data that can be remotely downloaded. Throughout the winter of 2016 we tracked fishers, and will use location data to test hypotheses about functional connectivity within this landscape in a way that genetic data cannot (but which likewise tells us things telemetry data cannot). Step selection functions[30,31] built from location data will enable us to test hypotheses about the connectivity between protected areas in this multi-use landscape.

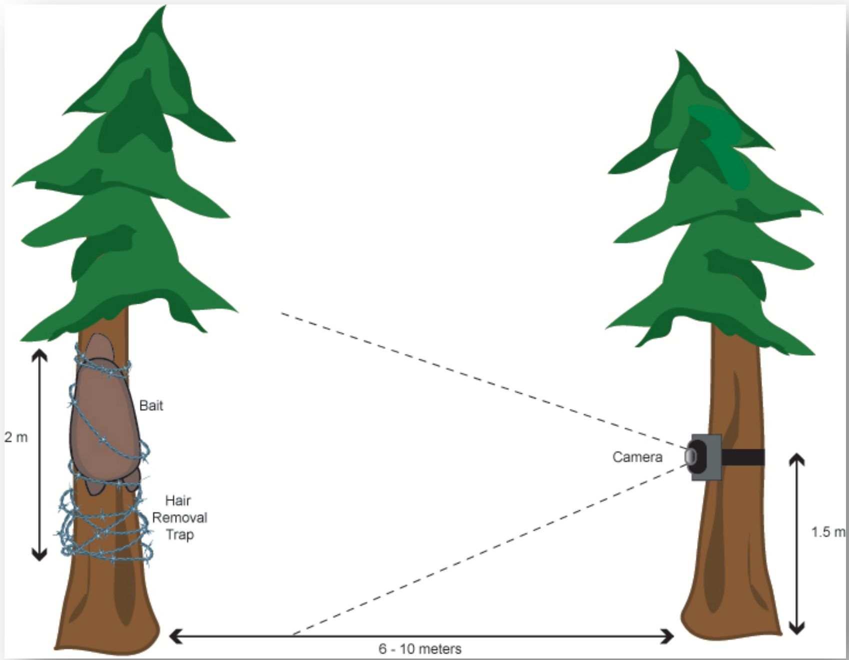


**Figure 2.** Mammal diversity is being surveyed at sampling sites using two methods: hair trapping for noninvasive genetic tagging, and camera trapping. The hair trap consists of barbed wire loosely wrapped around a baited tree. The Reconyx™ passive infrared-triggered digital camera is positioned on a tree 6-10m away to photograph the hair trap and the area around it (Fisher and Bradbury 2014).

## Statistical analysis

Camera surveys, like any survey, are challenged by the possibility of false absences: failing to detect a species that is, in fact, present. To assess the reliability of camera data, we must first estimate the probability of detecting that species if it is present at a site[28]. The frequency of repeated species detections at a camera can be used much like a mark-recapture history to estimate this probability of detection. Given this probability, we can correct for potential false absences and thus more accurately estimate the probability that fishers occupied a site during a sampling period. This *probability of site occupancy* takes into account missed detections, and because it describes the *likelihood* that a fisher uses a site, it is a more ecologically meaningful measure of a species' site-use than simply presence or absence, which is an all-or-none measure. Detectability and occupancy are estimated using hierarchical occupancy models[29], which are gaining widespread use for examining species' distributions ranging from wolverines[4] to salmon[32] and grizzly bears[33].

Occupancy is not a static measure; it is expected to change through time[34]. For example, sites without fisher can become occupied in the following season, whereas sites with fishers in one season may have no fishers in the next season, as they die, or emigrate to better habitat. Examining how occupancy changes among seasons helps us better understand the influence of environmental conditions on fisher distribution.

We used multi-season occupancy models[29,34] for a preliminary assessment of detectability and occupancy of fishers from 2014 camera data; we will conduct another assessment with both 2014 & 2016 data once data has been sorted from the 2016 field season. We assumed that each month of camera sampling represents a distinct and independent survey. We assumed that fisher occupancy could change between seasons, however, as individuals give birth, die, immigrate or emigrate between patches. We therefore divided the sampling period into 4 seasons, with 2 monthly surveys within each: Nov-Dec (autumn), Jan-Feb (winter), Mar-Apr (breeding), and May-Jun (kit emergence). Each season is assumed to be closed to changes to occupancy at the species level – that is, fishers will not disappear completely from a site, appear if absent, within each season, but can change between seasons. The assignment of seasons here is somewhat arbitrary and can change to suit species biology.

We also assumed the probability of detecting a fisher on camera – given it is present – could stay the same, vary among surveys or seasons, or vary monthly within seasons. Finally, we tested whether fishers were more likely to occupy sites within protected areas or outside protected areas. We ran a model with each set of assumptions, and ranked each model by its AIC score (Akaike's Information Criterion) – a measure of how well each model fit the data[35]. AIC scores weights were normalised to sum to 1.0 to create AIC weights, analogous to the probability that a model best explained the data, compared to other models in the set.

In the coming year, landscape structure will be quantified from available GIS data. We will use a combination of occupancy modelling[28,29] and generalized linear modelling[36] to examine relationships between species occurrence and habitat features. Multiple competing hypotheses will be represented as multiple statistical models, which we will rank[35] based on how well each model fits the data. The best-supported models indicate those natural landscape features and agricultural patches that best explain mesocarnivore occurrence on the moraine, and model parameter estimates will allow us to map the probability of occurrence of species across this landscape.

## Results

We deployed a total of 64 sampling sites across the Cooking Lake Moraine and sampled them monthly from November 2013 to June 2014, and this year from November 2015 to April 2016. To date we have collected 230,118 photos and 750 hair samples across the study area.

### Mammal communities

Moose (*Alces alces*), white tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*) red fox (*Vulpes vulpes*), coyote (*Canis latrans*), wolf (*Canis lupus*), least (*Mustela nivalis*), short-tailed *(Mustela erminea*) and long-tailed (*Mustela frenata*) weasels, porcupine (*Erethizon dorsatum)*, striped skunk (*Mephitis mephitis*), wood bison (*Bison bison athabascae*), elk (*Cervus canadensis*), black bear (*Ursus americanus*), striped skunk (*Mephitis mephitis*), cougar (*Puma concolor*), and domestic animals such as the domestic dog (*Canis lupis familiaris*) were also detected, illustrating that mammalian diversity is high across this landscape. Analysis of these data will be conducted in 2016-2017.

### Fisher distribution and genetics

Fishers were detected *via* cameras at 45 of 61 sites checked to date (70%), indicating that this species is widespread across the Moraine landscape and occupying a variety of habitat types. The probability of detecting fishers within a month-long camera survey (given they were present at a site; *p*) varied across time. The probability of fisher occupancy was also highly variable across the study area. The best-supported model, which carried almost all of the weight of evidence (AICw = 0.9997), indicates that *p* was different for each monthly survey (Table 1). There was a low probability of detecting fishers on cameras at the onset of the study, in November and December. This probability improved throughout the winter, peaking in February and March. Detectability in May and June was very low (Figure 3).

After accounting for imperfect detectability, there was a significant difference in fisher occupancy inside and outside of protected areas. Fishers were ~ 4.5 times more likely to occur at camera sites within protected areas ($\psi = 0.76$, s.e. = 0.11) than sites outside of protected areas ($\psi = 0.16$, s.e. = 0.07). There was no evidence that fisher occupancy varied among seasons, and their distribution was stable throughout the study period. These are preliminary models without spatial covariates derived from GIS data, and with assumptions about seasons and surveys that deserve scrutiny[37]. These models will be supplemented with data from the 2015-2016 field season, and with data quantifying anthropogenic and landscape features, to yield final results of fisher and competitor mesocarnivore species occupancy across the CLM across two years.

Table 1. Selection of competing occupancy models of fisher distribution, each with different assumptions about probability of detection and fisher occupancy. The best-supported model is highlighted.

| Detectability varies: | Occupancy varies: | AIC | ΔAIC | AIC weight | Model Likelihood | # parameters |
|---|---|---|---|---|---|---|
| Constant | Constant | 472.45 | 89.97 | 0.00 | 0.00 | 3.00 |
| Seasonally | Constant | 428.63 | 46.15 | 0.00 | 0.00 | 6.00 |
| Among survey months | Constant | 398.54 | 16.06 | 0.00 | 0.00 | 10.00 |
| Within seasons | Constant | 474.37 | 91.89 | 0.00 | 0.00 | 4.00 |
| Constant | Protected areas | 461.44 | 78.96 | 0.00 | 0.00 | 4.00 |
| Seasonally | Protected areas | 409.20 | 26.72 | 0.00 | 0.00 | 7.00 |
| ***Among survey months*** | ***Protected areas*** | ***382.48*** | ***0.00*** | ***1.00*** | ***1.00*** | ***11.00*** |
| Within seasons | Protected areas | 463.38 | 80.90 | 0.00 | 0.00 | 5.00 |
| Constant | Seasonally | 469.33 | 86.85 | 0.00 | 0.00 | 6.00 |
| Seasonally | Seasonally | 458.00 | 75.52 | 0.00 | 0.00 | 9.00 |
| Among survey months | Seasonally | 457.81 | 75.33 | 0.00 | 0.00 | 13.00 |
| Within seasons | Seasonally | 471.32 | 88.84 | 0.00 | 0.00 | 7.00 |

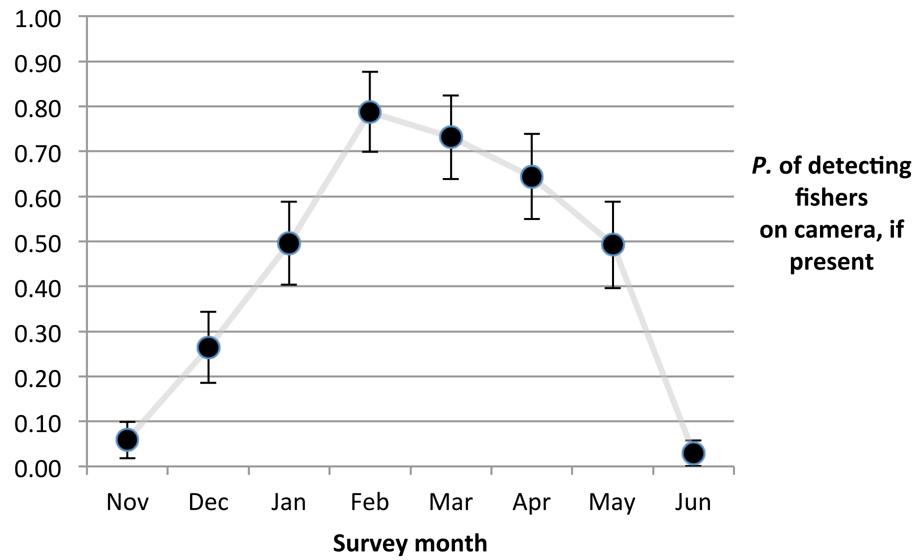


Figure 3. The probability of detecting fishers on cameras ($p$) varied with survey month. As with many studies, $p$ started low, then generally increased through time. Bars represent standard errors. High $p$ gives us confidence in conclusions about fisher distribution.

We are also determining whether CLM fishers are descendants from north and west of our study. Preliminary mitochondrial DNA analyses suggest that there is no difference between genetic samples from Alberta's Cold Lake and a single sample from CLM (Figure 4), more testing is needed with our full complement of samples.

## Fisher movement

We live-trapped and GPS-collared 14 fishers. Of these, we obtained GPS telemetry locations from 5 individuals so far, and are hoping to recover more data from additional collars. From these limited observations we cautiously see that fishers moved widely around the landscape and may use undisturbed forest as activity centres and "stepping stones" across areas of developed landscape (Figure 5). A full analysis of home ranges and movements will occur in 2016-2017.

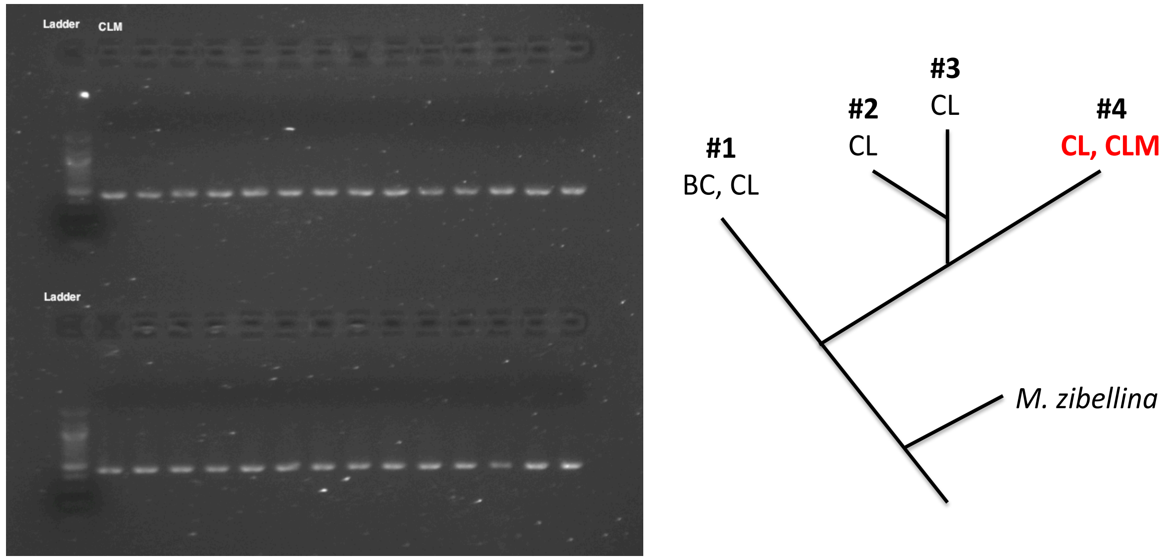


**Figure 4.** Electrophoretic gel of PCR product from *Pekania pennanti* D-loop mitochondrial DNA conducted by Frances Stewart (**left panel**). The first sample was collected from a road kill fisher in the Cooking Lake Moraine (CLM) and is not significantly larger than all other samples collected from the Cold Lake Area, as represented here. DNA sequencing later confirmed that the CLM sample represents the same haplotype as many other samples collected from Cold Lake as demonstrated by a phylogenetic tree (**right panel**) where the CLM clusters into the same haplotype (#4) as Cold Lake samples (CL). This analysis has yet to be repeated across all CLM samples collected to confirm this preliminary result.


**Figure 5.** Movement path of Fisher male "M01", overlaid on Google Earth imagery, shows the complex network of movements over a two week period. The width of the figure represents 6km.

## Discussion

Fishers were more widespread than expected. After accounting for imperfect detectability, fishers occupied an estimated 75% of sites within protected areas, and only 16% of sites outside of protected areas. The models require some refining based on assumptions about seasonality and movement, as well as the inclusion of spatial covariates describing landscape composition and configuration. However, these initial results provide strong evidence that protected areas play an important role in fishers' distribution.

Through camera photos we have been able to document multiple fisher individuals at some locations. Genetic analysis confirms the presence of 16 individuals, some with overlapping home ranges. Mammalian diversity was also high across multiple landcover types in this mixed-use landscape. We plan to further investigate interspecific interactions between mesocarnivores as our study continues.

The number of hair samples collected during each monthly check increased from 50 (January 2014) to 150 (April 2014); camera data increased from 18,050 (January) to 31,353 (April). These are mirrored in the probability of detection, which varies among surveys but is very high is later winter / early spring, similar to Fisher and Bradbury [27]. This suggests the method is quite sound and the data can be reliably used for species-habitat models to answer our primary questions.

### Community Involvement

We have contacted over 50 landowners and received the support of 26 of them for this project. The support of private landowners has been very encouraging throughout 2014-2016, and the project has been the focal point for community discussions about conservation. We also incorporated six CSL (Community Service Learning) students from Augustana Campus, University of Alberta, to help us input data from camera pictures and complete some basic fieldwork in spring 2014 & 2016. We have engaged *Friends of Elk Island Society* in this project, and they have assisted with camera deployment and checking (see http://www.elkisland.ca/conservation-research/mesocarnivore-monitoring). We have also engaged the *Beaver Hills Initiative*, securing financial and in-kind (GIS data) support, and their help in engaging their membership with outreach activities. Environment Canada, Ontario MNR, Trent

University, and Manitoba DNR have all helped procure samples for this project. The University of Victoria has provided genetic laboratory space free of charge.

This work to date was presented twice at the annual meeting of the FEIS to an audience of 70 people each time; the Alberta Trail Rider's Association; the Friends of Cooking Lake / Blackfoot Provincial Recreation Area; and the Strathcona All Horse Association. We received very positive feedback from the local community, with dozens of people offering their time for fieldwork in both 2014 and 2016. One of the things we like best about this research is the opportunity to involve local Albertans in ecological research in their own backyards.

## Preliminary Conclusions

Although the project is ongoing and much more work needs to be done, we can (cautiously) make some preliminary conclusions.

Most importantly, initial analyses suggest protected areas play a key role in maintaining fishers in this mixed-use landscape. Fishers were ~ 4.5 times more like to occur within a protected area, than outside a protected area. Movement data from GPS collars will markedly increase our ability to resolve the importance of protected areas in fisher habitat selection.

To date, the quantity of both hair samples and photos collected increased from January to April of this study, but decreased across the spring months. This observation is confirmed by the analysis of detectability via cameras; detectability peaked during late-winter months. This suggests that animals acclimated to the sites, climbing the barb-wired tree more frequently as daylight and temperature increased; however alternate food sources were available during the summer months and caused a decrease in both animal occurrence and hair samples at the baited sites.

Finally, we have shown that functional connectivity between the CLM and disjunct forested areas elsewhere in the province may be high for fishers. The CLM population appears to be derived from immigrants from elsewhere in Alberta – not descendants of the re-introduced animals. Final sampling and analysis is needed to confirm this conclusion.

The plan for 2016-2017 is to complete genetic analyses and begin to analyze data from wildlife cameras, genetics, GPS collars, and GIS landscape variables. We will spend the year or more analyzing these four data sets. This summer we will start statistical analyses, and in the fall we will continue with genetic analyses of both microsatellite (through Wildlife Genetics International) and mitochondrial (University of Victoria) analyses.

We continue to receive support and excitement on our findings from the Friends of Elk Island Society, local landowners, and the Beaver Hills Initiative. Collaboration through funding opportunities is vital to the completion of our study, which with field work now complete involves finishing genetic analyses, GIS analyses, and statistics. These data, and the associated analyses, are crucial to better understand how mixed-use landscapes of protected areas and agricultural areas contribute to mammalian biodiversity and ecosystem function.

## References


1 Parrish, J. D., Braun, D. P. & Unnasch, R. S. Are we conserving what we say we are? Measuring ecological integrity within protected areas. *BioScience* **53**, 851-860 (2003).

2 Sorensen, T. *et al.* Determining Sustainable Levels of Cumulative Effects for Boreal Caribou. *Journal of Wildlife Management* **72**, 900-905, doi:10.2193/2007-079 (2008).

3 Hervieux, D. *et al.* Widespread declines in woodland caribou (Rangifertaranduscaribou) continue in Alberta. *Canadian Journal of Zoology* **91**, 872-882, doi:10.1139/cjz-2013-0123 (2013).

4 Fisher, J. T. *et al.* Wolverines (Gulo gulo luscus) on the Rocky Mountain slopes: natural heterogeneity and landscape alteration as predictors of distribution. *Canadian Journal of Zoology* **91**, 706-716 (2013).

5 Schneider, R., Dyer, S. & Parks, C. *Death by a thousand cuts: impacts of in situ oil sands development on Alberta's boreal forest*. (Pembina Institute and Canadian Parks and Wilderness Society, 2006).

6 Dunning, J. B., Danielson, B. J. & Pulliam, H. R. Ecological processes that affect populations in complex landscapes. *Oikos*, 169-175 (1992).

7 Pulliam, H. R. Sources, sinks, and population regulation. *American Naturalist*, 652-661 (1988).

8 Pulliam, H. R. & Danielson, B. J. Sources, sinks, and habitat selection: a landscape perspective on population dynamics. *American naturalist*, S50-S66 (1991).

9 Goodwin, B. J. & Fahrig, L. How does landscape structure influence landscape connectivity? *Oikos* **99**, 552-570 (2002).

10 Andren, H. Effects of habitat fragmentation on birds and mammals in lanscapes with different proportions of suitable habitat: A review. *Oikos* **71**, 355-366 (1994).
11 Fahrig, L. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 487-515 (2003).
12 Fahrig, L. Relative effects of habitat loss and fragmentation on population extinction. *The Journal of Wildlife Management*, 603-610 (1997).
13 Middleton, J. & Merriam, G. Distribution of woodland species in farmland woods. *Journal of Applied Ecology*, 625-644 (1983).
14 Henderson, M., Merriam, G. & Wegner, J. Patchy environments and species survival: chipmunks in an agricultural mosaic. *Biological Conservation* **31**, 95-105 (1985).
15 Bennett, A. F., Henein, K. & Merriam, G. Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. *Biological Conservation* **68**, 155-165 (1994).
16 Taylor, P. D., Fahrig, L., Henein, K. & Merriam, G. Connectivity is a vital element of landscape structure. *Oikos*, 571-573 (1993).
17 Fisher, J. T. & Merriam, G. Resource patch array use by two squirrel species in an agricultural landscape. *Landscape Ecology* **15**, 333-338 (2000).
18 Miller, J. R., Morton, L. W., Engle, D. M., Debinski, D. M. & Harr, R. N. Nature reserves as catalysts for landscape change. *Frontiers in Ecology and the Environment* **10**, 144-152 (2012).
19 Prugh, L. R. *et al.* The Rise of the Mesopredator. *BioScience* **59**, 779-791, doi:10.1525/bio.2009.59.9.9 (2009).
20 Terborgh, J. & Estes, J. A. *Trophic cascades: predators, prey, and the changing dynamics of nature*. (Island Press, 2010).
21 Fisher, J. T., Boutin, S. & Hannon, a. S. J. The protean relationship between boreal forest landscape structure and red squirrel distribution at multiple spatial scales. *Landscape Ecology* **20**, 73-82, doi:10.1007/s10980-004-0677-1 (2005).
22 Nichols, J. D. *et al.* Multi-scale occupancy estimation and modelling using multiple detection methods. *Journal of Applied Ecology* **45**, 1321-1329 (2008).
23 Waits, L. P. & Paetkau, D. Noninvasive genetic sampling tools for wildlife biologists: a review of applications and recommendations for accurate data collection. *Journal of Wildlife Management* **69**, 1419-1433 (2005).
24 O'Connell, A. F., Nichols, J. D. & Karanth, K. U. *Camera traps in animal ecology: methods and analyses*. (Springer Tokyo, 2011).
25 Fisher, J. T., Anholt, B., Bradbury, S., Wheatley, M. & Volpe, J. P. Spatial segregation of sympatric marten and fishers: the influence of landscapes and species-scapes. *Ecography* **36**, 240-248 (2012).
26 Fisher, J. T., Anholt, B. & Volpe, J. P. Body mass explains characteristic scales of habitat selection in terrestrial mammals. *Ecology and Evolution* **1**, 517-528 (2011).
27 Fisher, J. T. & Bradbury, S. A multi‐method hierarchical modeling approach to quantifying bias in occupancy from noninvasive genetic tagging studies. *The Journal of Wildlife Management* **78**, 1087-1095 (2014).
28 MacKenzie, D. I. *et al.* Estimating site occupancy rates when detection probabilities are less than one. *Ecology* **83**, 2248-2255 (2002).

29 MacKenzie, D. I. *et al. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. (Academic Press, 2006).
30 Manly, B. F., McDonald, L. & Thomas, D. L. *Resource selection by animals: statistical design and analysis for field studies; 2nd Edition*. (Springer, 2002).
31 Thurfjell, H., Ciuti, S. & Boyce, M. S. Applications of step-selection functions in ecology and conservation. *Movement Ecology* **2** (2014).
32 Fisher, A. C., Volpe, J. P. & Fisher, J. T. Occupancy dynamics of escaped farmed Atlantic salmon in Canadian Pacific coastal salmon streams: implications for sustained invasions. *Biological Invasions*, 1-10 (2014).
33 Fisher, J. T., Wheatley, M. & Mackenzie, D. I. Spatial patterns of breeding success of grizzly bears derived from hierarchical multistate models. *Conservation Biology* **28**, 1249-1259 (2014).
34 MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G. & Franklin, A. B. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* **84**, 2200-2207 (2003).
35 Burnham, K. P. & Anderson, D. R. *Model selection and multi-model inference: a practical information-theoretic approach*. (Springer Verlag, 2002).
36 Faraway, J. J. *Extending the linear model with R: generalized linear, mixed effects and nonparametric regression models*. (CRC press, 2004).
37 Burton, A. C. *et al.* Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology* **52**, 675-685, doi:10.1111/1365-2664.12432 (2015).

Patriquin, D. 2014. Landscape of Hope: The influence of place and social capital on collaborative action in sustainable management. University of Alberta, PhD thesis. Edmonton, Alberta, Canada.