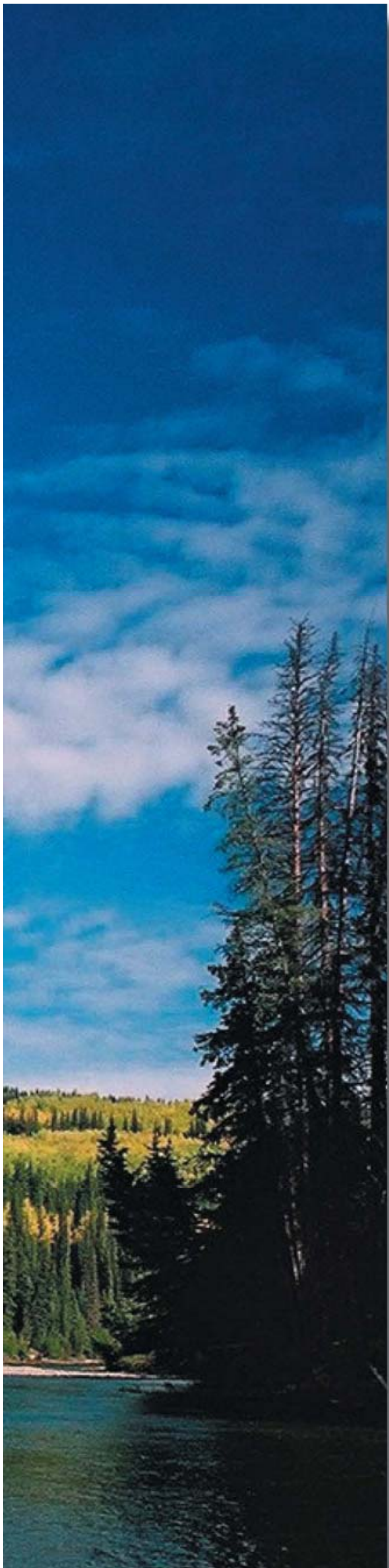

Wolverine Distribution and Habitat Associations on Registered Traplines in Alberta, Winters 2011/12 – 2015/16

Alberta Conservation Association

The Alberta Conservation Association is a Delegated Administrative Organization under Alberta's Wildlife Act.

Wolverine Distribution and Habitat Associations on Registered Traplines in Alberta, Winters 2011/12 – 2015/16

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EXECUTIVE SUMMARY

Alberta Trappers' Association and Alberta Conservation Association (ACA) collaborated on a unique citizen science partnership to determine broad-scale distribution and habitat associations of wolverines using long-term fur harvests, trapper questionnaires and field data. We conducted a detailed review of historical fur harvests to examine how wolverine distribution has varied across the province over time. We then conducted a questionnaire survey with trappers to determine locations where wolverines were present or absent, perceptions of wolverine population trends, trapper attitudes and effort, and course-scale habitat associations based on trappers' responses. The final component of our study relied largely on trapper volunteers to inventory wolverines on their registered traplines. We collected field data using non-invasive run pole camera traps designed to photograph wolverines so biologists could differentiate individuals based on unique throat and chest markings. Trappers donated tissue samples from harvested wolverines, and the run poles collected hair samples for genetic (DNA) analysis. This report discusses our findings from the early stages of testing methods in various regions of the province between 2011 and 2013 to the later stages of inventorying wolverines and other wildlife in the Boreal Forest between 2013 and 2016.

In total, 154 run pole camera traps were operated by 31 trappers, along with ACA staff, on 56 registered traplines in the Boreal Forest (2013 – 2016). The camera traps were effective at detecting a wide range of species and worked particularly well for attracting furbearers. Cameras detected wolverines at about 33% of the sites, fishers at 57% of the sites, and lynx at 49% of the sites. In total, 56 different wolverines (16 males, 10 females, 30 unknown) were identified from photos taken in the Boreal Forest (2013 – 2016). We also identified lactating females (n = 6; 2011 – 2016) and documented interesting behaviours between species and individuals. In the Boreal Forest, we detected wolverines from 56° to 59°N (n = 115 sites), but no wolverines were detected from 54° to 56°N (n = 39 sites). Wolverine occurrence was positively associated with undeveloped forest, deeper winter snow depths, and a cooler theoretical temperature index, and negatively associated with density of roads and oil and gas wells.

We identified five wolverine haplotypes (A, C, D, F, L) from hair and tissue samples. In the Rocky Mountains (n = 13 individuals), the genetic analysis indicated that Crowsnest Pass and Grande Cache areas had similar haplotypes, "A" (54%) and "L" (46%). In the Boreal Forest (n = 70 individuals), haplotype "C" (also found in the Cascade Mountains of Washington and southern British Columbia, Northwest Territories, Nunavut and Saskatchewan) and

haplotype “A” (found in the western United States and across Canada) were most prevalent (C: 47%; A: 33%). Haplotype “F” (17%) and haplotype “D” (3%) were the least common haplotypes in the Boreal Forest, but our study was the first to identify haplotype “D” in wolverines from Alberta.

Non-invasive camera traps maintained by trapper citizen scientists were successful at detecting wolverines and many other wildlife species, demonstrating the potential usefulness of cameras in long-term monitoring studies. Working directly with passionate stakeholders to plan and implement research had mutual benefits. This collaborative effort has increased our understanding of wolverine ecology, behaviour, and habitat associations, particularly in the Boreal Forest, and will be a timely contribution to an updated species status assessment in the future.

Key words: Alberta, Boreal Forest, camera trap, habitat, haplotype, run pole, trapline, wolverine.

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1.0 INTRODUCTION

The status of wolverines (*Gulo gulo*) in Alberta was reviewed in the late 1990s and determined to be *Data Deficient* (Alberta Environment and Parks 2015). Although there was insufficient data to determine whether wolverines were at risk, based on their sensitive life history traits, wolverines continued to be classified as a furbearer under a quota system (one wolverine is allowed to be harvested annually per registered trapline; Government of Alberta 2015). Federally, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) considers wolverines as *Special Concern* (COSEWIC 2014). Meanwhile, wolverines in the contiguous United States have been contentiously considered for federal protection as *Threatened* under the Endangered Species Act (United States Fish and Wildlife Service 2014). Because of estimated low numbers, there is currently no trapping season on wolverines in the United States (except Alaska), and research continues to be undertaken to better understand their ecology, habitat needs and population threats across their range. Wolverines are both cryptic and difficult to catch, so even basic information on them is challenging to obtain. These factors, coupled with a vast home range and naturally occurring low densities (Banci 1994), continue to make wolverines one of the least understood carnivores. In 2011, members from the Alberta Trappers' Association (ATA) approached biologists at Alberta Conservation Association (ACA) with a proposal to work in partnership to address the identified data gaps for this species, thereby contributing to the assessment of the status of the species in the province and ensuring that sound science was being used to manage this furbearer for long-term sustainable harvest.

What little is known about wolverines in Alberta has been derived from fur trapping records and anecdotal information. A trapper opinion survey in 1987 indicated that wolverines were declining throughout Alberta (Skinner and Todd 1988). The status of wolverines in the province was assessed, in large part, using trapping records compiled by Petersen (1997), which showed a downward trend in wolverine harvests through time (1972 – 1995). Poole and Mowat (2001) also used trapping records to assess distribution and population trends of furbearers in Alberta. Wolverine harvest trends from 1977 – 1999 showed a general decrease with reduced distribution over time (Poole and Mowat 2001); however, the data were not corrected by the wolverine quota initiated in 1989, which could have influenced the downward trend. In 2012, we analyzed the trapping data to evaluate more recent spatial and temporal trends in wolverine harvest. We found that the annual number of registered traplines harvesting a wolverine and the mean number of harvested wolverines had increased since the early 1990s (Webb et al. 2013). When data from 1989 to 1999 (n = 246 wolverines) and 2000 to 2012 (n = 390 wolverines) were compared, mean wolverine harvest density (annual number of wolverines caught during each time period per unit area) increased by 75% in the northwest (NW) Boreal and 20% in the northeast (NE) Boreal. During the same time period, mean wolverine harvest density declined by roughly 45% in the Rocky Mountains and Canadian Shield; however, this represented a small change in annual harvest of approximately 0.05 animals/1,000 km^2 (i.e., 1 – 2 animals/year in the Rocky Mountains and 0 – 1 animals/year in the Canadian Shield).

To gather more information on the current status of the wolverine population, we conducted a trapper questionnaire survey in 2012. Our objectives were to determine locations where wolverines were present or absent, perceptions of wolverine population trends, and trapper attitudes and effort, and to relate wolverine occurrence to coarse-scale habitat factors. We received responses from 164 trappers representing 176 registered traplines across the province. Based on trapper responses, we obtained a clearer understanding of wolverine distribution and of the types of places where wolverines were likely and unlikely to occur. The per cent of registered traplines in each region where a wolverine had been detected was highest in the NW Boreal (85%) and Rocky Mountains (85%), followed by the Foothills (67%) and NE Boreal (48%). In the Boreal Forest (n = 91 traplines), wolverine occurrence was significantly associated with traplines that had more potential food (ungulates), were more remote, and had cooler climates with deeper snow depths. In the Foothills/Rocky Mountains (n = 73 traplines), wolverines were more likely to be found closer to snow-covered areas in spring and closer to undeveloped, intact forest.

Over the last decade, researchers have made a lot of progress in gathering data on wolverines in Alberta, with most of the work concentrated in the mountains (Fisher et al. 2013; Stewart et al. 2016). These studies show that the distribution and behaviour of wolverines may be negatively affected by the human footprint. Using cameras and genetic tagging, Fisher et al. (2013) estimated there were 6.8 wolverines/1,000 km^2 in the less developed Willmore Wilderness Park and 1.8 wolverines/1,000 km^2 in the more developed surrounding areas. Few wolverines were detected in the Foothills, and wolverines that did show up were hesitant to climb the baited trees and spent less time at sites compared with wolverines detected in protected or less developed landscapes (Stewart et al. 2016). Clevenger et al. (2016) also found a similar trend, with the lowest proportion of sites occupied by wolverines in the west-central Foothills (0.14) and highest occupancy in the Banff-Yoho-Kootenay Park complex in the mountains (0.88). Anthropogenic disturbance may also affect species negatively through increased interspecific competition (Heim 2016). These studies all suggest that wolverines are limited by human activities and development, yet it is difficult to untangle the causes of occurrence because variables are often correlated. Wolverines have been shown to occur in places with more rugged terrain, which typically occurs in alpine areas with deep snowpack, less development, and no trapping (in the mountain national parks). Applying findings from the mountains across the wolverine's range may not be appropriate or accurate given vastly different habitats.

Wolverines living in boreal landscapes have received little attention despite the large area that this habitat type represents. The final component of our research partnership was to conduct a field inventory of wolverines across the province and then to concentrate specifically on the Boreal Forest, identifying habitat variables associated with home range habitat selection and characterizing wolverine DNA to better understand how animals in Alberta are related to those in neighbouring areas. Equal in importance to our organizations' research goals was the desire to work with volunteer trappers to achieve these objectives. By partnering with trappers to collect field data, we wanted to capitalize on the opportunity to engage with an experienced stakeholder group eager to work with researchers toward a common purpose. Citizen science has been found to be particularly cost-effective in documenting large-scale processes over wide spatial and temporal extents (Devictor et al. 2010). Also, the scientific and educational components of citizen science programs have wide-reaching conservation effects on the volunteers involved in the research. The Christmas Bird Count held annually in North America is an example of one of the most successful and longest running citizen science programs; it has involved thousands of people to document bird species since the 1900s. Engaging local recreationalists and incorporating multigenerational traditional knowledge has been shown to boost project success and aid in conservation efforts (Granek et al. 2008; Webb and Anderson 2016). Furthermore, citizen science research has been shown to be scientifically robust under appropriate methodologies, statistical design and training. Models derived from citizen science initiatives can be highly accurate and provide reliable data for wildlife research, particularly with experienced volunteers (Nagy et al. 2012). Our project takes this concept a step further in that it was a *citizen-initiated* science project. It was not the researchers who were asking volunteers to help them pursue their questions, which is usually what happens; in this case, it was the trappers who approached the scientists and asked for assistance in collecting robust data on Alberta's wolverines.

Within this context, we aimed to work with trappers across the province to test and implement methods that effectively capture photos and DNA samples of wolverines. DNA-based methodologies have provided reliable, cost-effective and robust population estimates that can be used to monitor wolverines (Schwartz et al. 2006). Information from genetic samples has also been used to investigate how wolverines are related across North America (McKelvey et al. 2014; Schwartz et al. 2009; Zigouris et al. 2012) and even to draw conclusions about how the species has responded geographically to events such as ice ages and suspected extirpation from the contiguous United States in recent centuries (McKelvey et al. 2014). We will explore the genetic structure of wolverines from hair and tissue samples collected in Alberta and compare it to that reported for other jurisdictions. In addition to the work presented in this report, we anticipate collaborating with other researchers to use established techniques to analyze broad-scale genetic relationships for wolverines.

Based on earlier findings from wolverine harvests and trapper questionnaires, we hypothesized that wolverine occupancy in the Boreal Forest would be associated with areas that were more remote and further from towns, had less industrial development, and had cooler climates. But at a finer scale, we expected to find a stronger positive association between wolverine occupancy and food resources, specifically habitats that would support snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*) and ungulates. The literature suggests that ungulates are an important food source for wolverines, particularly in late winter and early spring, whereas smaller, more reliable prey items can be important in summer and fall (Inman et al. 2012). We expected a positive association between places predicted to have good productivity for ungulates (Environment Canada 1972) and places we thought would have good habitat for beavers (i.e., fen, bog and open water) and snowshoe hares (i.e., conifer forest). Our assumptions regarding the importance of late spring snow cover changed over the course of our study; ultimately, we did not expect to find a strong association between wolverine occupancy and the persistent spring snow cover thought to provide important denning structure (Copeland et al. 2010) based on our analysis of females and snow cover (Webb et al. 2016). Given wolverines are capable of moving long distances, we expected DNA samples from different areas would have high overlap in genotypes, indicating good gene flow between the Boreal Forest and Rocky Mountains.

2.0 STUDY AREA

We collected data from Registered Fur Management Areas (i.e., registered traplines). Registered traplines (n = 1,667) primarily overlap forested Crown (public) land where individuals have a licence to trap furbearers in a specific area, as managed by Alberta Environment and Parks (Figure 1). Created in 1938, the registered trapline system was meant to limit competition, prevent overharvest and improve the overall management of furbearers (Pybus 2005). No trapping occurs in national parks, except for Wood Buffalo National Park in northern Alberta. We initially worked with trappers to test methods in the Rocky Mountains, Foothills and Boreal Forest Natural Regions. The Rocky Mountains Natural Region is located along the western provincial border and consists of montane, subalpine and alpine subregions, with elevations from 1,000 to 3,700 m (Natural Regions Committee [NRC] 2006). The Rocky Mountains are dominated by coniferous forests at lower elevations and snow, ice and rock at higher elevations, with limited industrial development and motorized access, but popular backcountry recreational areas. The Foothills Natural Region borders the mountains and has a mix of coniferous, mixed, and deciduous forest with multiple, overlapping land uses (e.g., timber harvest, oil and gas exploration and development, coal mines, cattle grazing, and recreation) and a wide gradient in access (road density range: 0 – 2.99 km/km^2, $\bar{x}$ = 0.56 km/km^2 ± 0.38 (SD), n = 442 traplines), and elevations from 700 to 1,700 m (NRC 2006). The Boreal Forest Natural Region is located north of the Foothills and Rocky Mountains, and it represents 58% of the province, with extensive wetlands interspersed among lowland coniferous forest and deciduous forest in the uplands, and elevations from 150 to 1,000 m (NRC 2006). During the last three winters (2013 – 2016), we focused our sampling on registered traplines that overlapped the Mackenzie watershed within the Boreal Forest (~54 – 60°N; Figure 1) in order to increase our understanding of an understudied wolverine population.

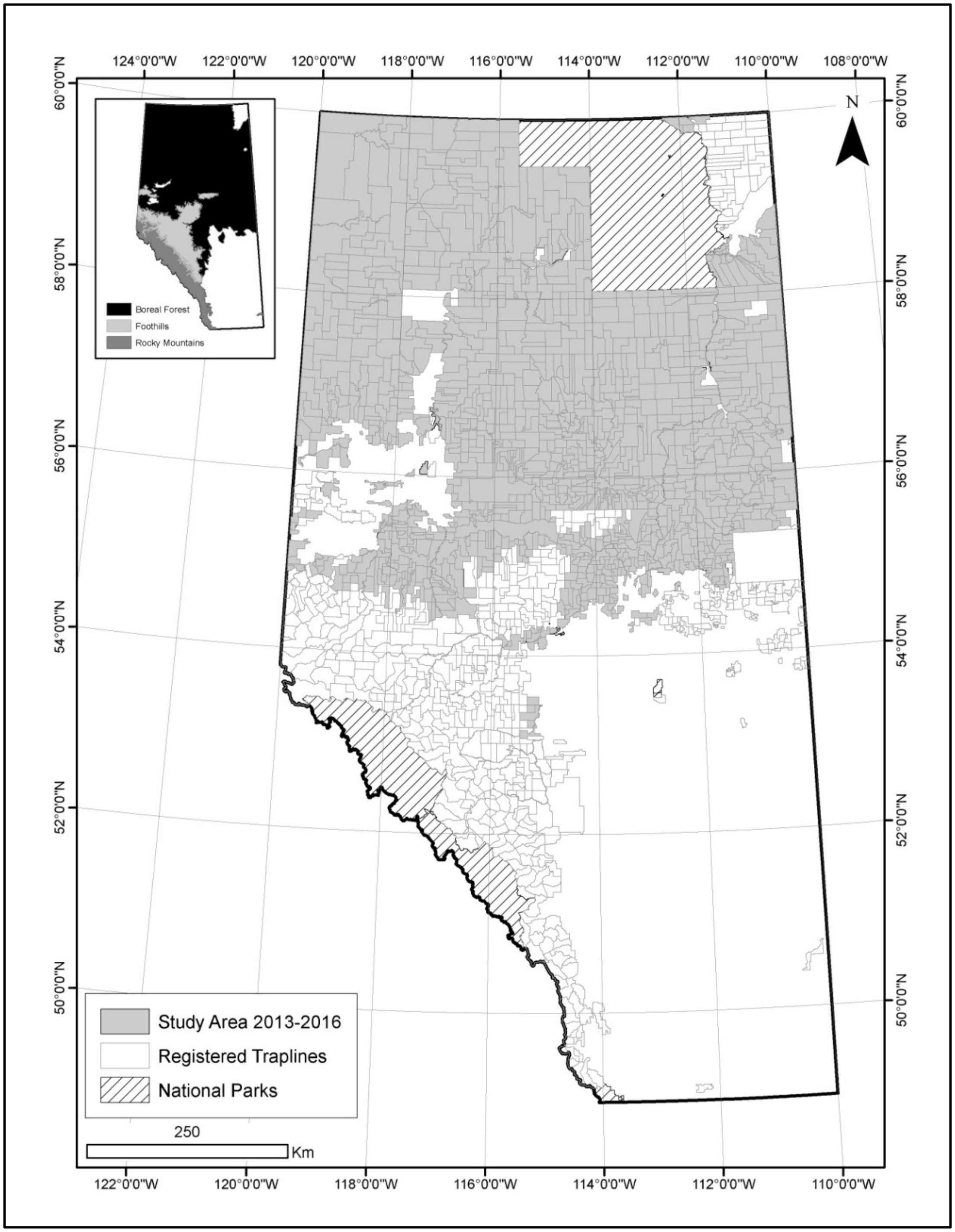

Figure 1. Registered traplines and selected natural regions in Alberta.

3.0 MATERIALS AND METHODS

We developed a study design that would be simple to follow and easy to replicate in the field by participants. We solicited trapper participation at multiple venues (e.g., presentations to local trapping meetings, trapping magazine articles, online trapping forum, annual trapping rendezvous). During year one (winter 2011/12) of the study, we tested the field protocol with a select group of trappers that had caught wolverines in the past in the Rocky Mountains and Boreal Forest. During year two (winter 2012/13), we increased our sample size and coverage to test and further refine the protocol in the Rocky Mountains, Foothills and Boreal Forest. During years three to five (winter 2013/14, 2014/15 and 2015/16), we used a consistent protocol to inventory wolverines on registered traplines in the Boreal Forest with and without a history of wolverines.

3.1 Camera/hair snag protocol

We used the run pole method, a non-invasive, dual-approach to identify individual wolverines using cameras and hair snags (Magoun et al. 2011). We suspended a large chunk of bait high between two trees and secured a horizontal run pole to one of the trees so that the end of the pole was positioned just below the bait (Figure 2). As an animal walked along the run pole in an effort to get closer to the bait, its body brushed against open alligator clips that shifted upon movement and closed, pulling out hair samples in the process. As an animal tried to gain leverage to get closer to the bait overhead, it put its paws on a support bar and exposed a full frontal view (Figure 3). Situated a short distance away and across from the run pole was a movement-triggered camera that took continuous photos of all the action (i.e., main camera). Wolverines, like many other members of the weasel family, have light-coloured throat and chest markings that are unique to each individual. Using photos, we identified different wolverines simply based on unique chest patterns. We also used photos to document evidence of gender, lactation, scent marking, and other behaviours (Figure 3). We set a second camera at the site further away to photograph cautious animals that entered the general area but did not climb the run pole (i.e., secondary camera).

Figure 2. The camera/hair snag station. The station was composed of a run pole with alligator clips on either side of the pole that collect hair when an animal brushes against them, bait that is suspended just above and slightly out from the run pole crossbar, and a remote trail camera across from the run pole. A second camera was placed further away at the site to photograph cautious animals that entered the general area but did not climb the run pole.

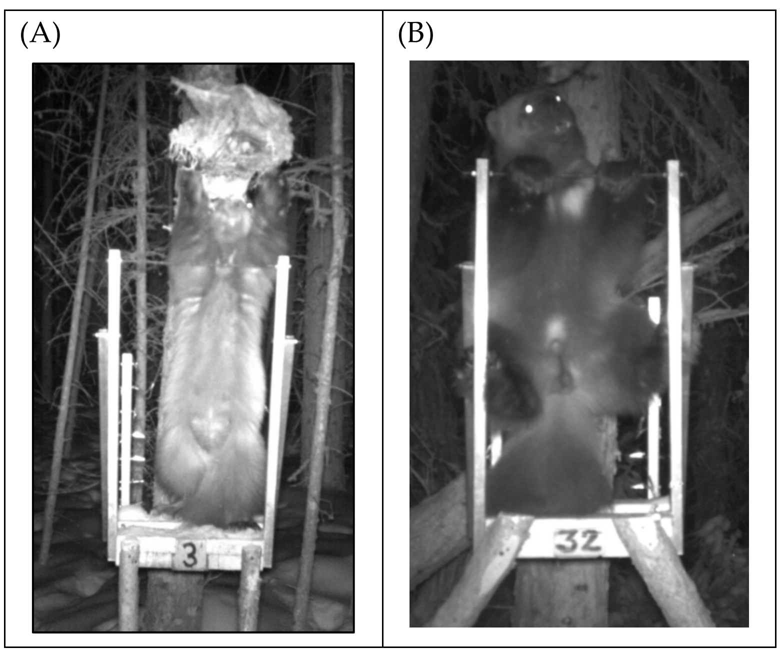

Figure 3. A frontal view of a lactating female wolverine that spent 15 hours at a run pole over the winter months near Rainbow Lake in 2013 (A) and a male wolverine that visited the Milligan Hills area in 2016 (B).

Trappers typically established one or two run pole sites on their registered trapline from November to March. A 10 km by 10 km township grid cell, meant to emulate a minimum female home range (Banci 1994), was randomly selected for each run pole within the designated trapline. Trappers had the flexibility to locate the run pole anywhere within the randomly selected township grid cell using their knowledge of the area. Selecting a random grid cell decreased bias associated with always putting the run pole in the "best" wolverine location and creating "biased high" numbers. With local trapper permission, ACA staff supplemented these sites with a small subset of run poles in areas where no volunteers were available. ACA staff also assisted new trappers to the study with setting up run poles, distributed beaver bait, and followed up monthly with each trapper for status updates throughout the winter season. We attempted to visit each trapper in the field at least once each winter to make sure protocols were being followed consistently, acquaint ourselves with the study area, and keep the lines of communication open. Often times, these visits would result in a trapper sharing ideas about important habitat types, which could later be tested with the larger dataset.

Run poles were checked approximately every two weeks to replenish bait/lure, download photos and collect hair samples. Each alligator clip was labelled so that it could be matched up to the photo event in order to determine which hairs were likely wolverines versus non-target species, thereby maximizing the cost-effectiveness of the hair analysis. Trappers collected hair samples from each alligator clip into separate envelopes, and ACA staff sorted out the probable wolverine samples. We submitted all wolverine hair and tissue, including opportunistic samples from trapper-harvested wolverines, to the National Genomics Center (Missoula, MT). The genetics lab tested samples and determined species, individual, gender and haplotype when adequate DNA was available (Schwartz et al. 2007). We amalgamated the findings from all hair and tissue samples and summarized DNA results from unique individuals to compare haplotypes found in the Rocky Mountains and Boreal Forest of Alberta.

3.2 Occupancy analysis

Occupancy is defined as a location where a species is present and is often measured by the proportion of sites a species is observed (MacKenzie et al. 2006). However, animals may be present but go undetected, which could lead to biased occupancy estimates and misleading habitat models. Therefore, we used methods to account for detectability, which can help correct occupancy estimates (MacKenzie et al. 2006). Although we present general results from across the province, we only report detailed occupancy analysis results for data collected from the last three winters (2013/14, 2014/15 and 2015/16), when protocols and study area were consistent. We used a model-based approach to estimate occupancy and detection simultaneously while evaluating multiple competing hypotheses (Burnham and Anderson 2002; MacKenzie et al. 2006). We used program Presence to model occupancy and detection using several different modelling frameworks.

We examined single species–single season models to determine the overall occupancy by site, region, habitat type and disturbance for each winter. We identified important variables associated with wolverine occurrence and used the run pole results from winter 2014/15 to predict probability of wolverine occurrence across all townships in the Boreal Forest. We used a *t*-test to compare actual wolverine occurrence at run poles (2013 – 2016) and predicted occurrence to determine whether wolverines were typically associated with areas we expected to find them in. We explored community dynamics to determine whether there was evidence of co-occurrence or avoidance of wolverines and other species using a chi-squared test (observed versus expected). We selected a subset of our data where the same registered traplines were resampled at least two of the three winters to examine multi-season occupancy models. For the analysis, we used month (December, January, February and March) as our survey time frame. Finally, we pooled all of our data (2013 – 2016) to increase sample size and determine whether a species was ever detected. We only included sites that were at least 6 km apart so that sites were independent of each other (Heim 2016). When multiple sites were <6 km apart, we grouped them together, randomly chose which site we would include in order to measure habitat variables, and summed detections within the group to determine whether a wolverine was detected at a site in the area over the three winters. We used logistic regression to examine patterns in species occurrence at the township (home range) scale. We evaluated other furbearers detected at run poles and modelled their occurrence relative to habitat factors when sample sizes were adequate.

We included variables that have been shown to be important predictors of wolverine occurrence, such as prey, disturbance and climate (Appendix 1). We calculated most of the variables for each township in the Boreal Forest. To be more representative of the area, we created 5 km radius buffers around each site and calculated a mean of the overlapping township values within those circles (78.5 km^2). Weather station data were more spread out, so we measured winter snow depths using 10 km buffers around each site.

4.0 RESULTS AND DISCUSSION

4.1 Developing a citizen science camera/hair snag protocol (2011 – 2013)

We initially tested the run pole method with a subset of registered traplines (n = 7), trappers (n = 6) and run poles (n = 14) in the Rocky Mountains and Boreal Forest from January to March 2012. Trappers were selected based on location, experience, ability to volunteer their time and higher likelihood of wolverine occurrence. ACA provided all supplies necessary to set up and operate the prefabricated run poles. Trappers used their own tools, equipment and bait, and volunteered their time to set up run poles in their best wolverine habitats. A research grant allowed us to provide a small cost-recovery payment to trappers during the first four winters of the study to help cover their out-of-pocket expenses, given that we were asking them to be active in March after the prime trapping season was over. During the first winter, run poles were set as far apart as possible to increase the number of different individuals detected on traplines. Trappers, for the most part, continued their normal activities, including setting traps to catch wolverines and other furbearers. The goal was for the run pole sets to fit into trappers' typical trapping routine to increase convenience of participating in the study. However, we learned that it takes an hour or more to find and prepare a suitable site and set up the run pole properly. Frequent re-baiting was necessary for many areas (weekly to biweekly), bait quantity was important (bigger was always better), and a whole beaver or a half of a beaver was more effective bait than ungulate parts. There was also a learning curve to using the cameras and properly collecting hair. Overall, the winter was a success, and we recorded several wolverine visits and collected hair samples. Latency times (number of days to first wolverine visit) was variable across the sites (6 – 48 days), which indicated that it could take some time to detect wolverines even in the best of habitats. We made a few slight adjustments to improve the protocol and determined that a maximum of two run pole sets per trapper would be manageable. Using the image data, we identified 13 individual wolverines at 14 sites (4 males, 3 females, 6 unknown). On average, wolverines were spending 23 minutes at the run pole and were revisiting sites approximately every two days. We defined a visit when >1 hour had elapsed between visits. If a wolverine spent 30 minutes at a site and then left and came back 15 minutes later, that would be counted as one visit. If a wolverine spent 20 minutes at a site and came back 2 hours later, that would be considered two visits. The number of times a wolverine visited a site varied from one to 32 visits over the winter period, indicating habituation of some individuals. Wolverine visitation rates increased each month (January: 13 visits, February: 41 visits, March: 62 visits).

We tested and further refined the run pole protocol with a larger subset of registered traplines, with and without history of wolverines, during winter 2012/13. From November 2012 to March 2013, 25 trappers, along with ACA biologists, operated 50 run poles across 29 different registered traplines in the Boreal Forest (n = 20 sites), Rocky Mountains (n = 19 sites) and Foothills (n = 11 sites). We created several "how to" videos for trappers that guided them through the process of selecting a site, setting up a run pole, operating a camera, and collecting hair/tissue samples (YouTube search: wolverine project field protocol part 1, part 2, part 3, tissue sampling). ACA biologists were able to visit 56% of the trappers (n = 14) over the winter field season, and all six trappers from the first winter continued to participate in the study. Wolverine tracks were observed in 50% of the townships that had a run pole, whereas the cameras only observed wolverines at 23% of the sites and wolverine hair was collected at 6% of the sites. At several sites, a wolverine approached the run pole but did not climb it. As a result, in 2013/14 we added a second camera to each site further away from the run pole to increase the likelihood of detecting wary animals. Some of our sampling locations were in similar locations to the previous winter (Rainbow Lake and Sheep Creek), so we did have repeat visitors of at least two individuals. We collected 112 wolverine DNA samples, which included scat, hair and tissue from live and harvested individuals. In addition to wolverine hair samples (n = 91), we also received and archived hair samples from other wildlife species, including marten (*Martes americana*; n = 24), fisher (*Pekania pennanti*; n = 62), bobcat (*Lynx rufus*; n = 2) and cougar (*Puma concolor*; n = 10). We collected over 50,000 photos from cameras at run pole sites over the winter, with a minimum of 17 different wolverines identified from photos (3 males, 2 females, 12 unknown). Approximately 23% of run poles documented at least one wolverine visit from Sheep Creek, Rainbow Lake, Ponton River near High Level, Liege River near Birch Mountains, Hayden's Ridge near Grande Cache, and Crowsnest Pass. We documented one lactating female in the Rocky Mountains near Sheep Creek and one lactating female wolverine near Rainbow Lake that spent 15 hours at a run pole (the most time spent by any individual wolverine that winter; Figure 3).

Wolverine detection was highest in the NW Boreal (43%, n = 15) and Rocky Mountains (25%, n = 20); no wolverines were observed in the Foothills or NE Boreal, although we had few sites in those areas. Latency times were quite variable, ranging from 23 hours to 104 days. Similar to our first winter, we observed a trend for wolverine visits (each visit is separated by at least 1 hour) to increase each month (November: 12 visits, December: 19 visits, January: 15 visits, February: 21 visits, March: 32 visits), although this may be partly due to sampling effort (fewer sites were operated in November and December). The number of visits per wolverine varied from one to 21 visits, and the average time spent at the run pole by an individual wolverine was 2 hours. Only five wolverines visited once, whereas 12 wolverines visited a run pole more than once. Over the first two winters, at least 19 different species were detected in the Foothills and Rocky Mountains (4 weasel, 4 ungulates, 1 canid, 1 bear, 3 felid, 2 squirrel, 1 hare, and bird species; Table 1). The general conclusion from our initial two years of study was that the run pole method could be used effectively as a way for trapper citizen scientists to collect wolverine occurrence data over a large geographic area given appropriate project coordination and oversight. Our early results suggested that different factors may be influencing habitat selection in the Rocky Mountains and Boreal regions (in some cases in opposite directions), so we decided to focus future efforts on the Boreal part of the province to learn as much as we could about that understudied region.

Table 1. Proportion of sites that each species was detected by remote trail cameras in the Foothills and Rocky Mountains (2011 – 2013) and in the Boreal Forest (2013 – 2016).

Species	Foothills/Rocky Mountains	Boreal Forest
Canids		
Coyote	0	0.07
Red fox	0.06	0.05
Wolf	0	0.13
Felids		
Bobcat	0.03	–
Cougar	0.09	0.01
Lynx	0.15	0.49
Hare		
Snowshoe hare	0.12	0.10
Mustelids		
Fisher	0.06	0.57
Marten	0.41	0.36
Mink	0	0.01
Weasel	0.09	0.34
Wolverine	0.24	0.33
Squirrels		
Flying squirrel	0.18	0.14
Red squirrel	0.59	0.50
Ungulates		
Caribou	0	0.01
Elk	0.03	0.01
Feral horse	0.03	–
Moose	0.29	0.17
White-tailed deer	0.12	0.12
Ursids		
Black bear	0	0.05
Grizzly bear	0.03	0.01
Birds		
All species combined	0.38	–
Blue jay	–	0.01
Chickadee	–	0.05
Gray jay	–	0.39
Grouse	–	0.01
Magpie	–	0.01
Raven	–	0.19
Woodpecker	–	0.01

4.2 Boreal forest inventory (2013 – 2016)

4.2.1 Camera results

In total, 154 run pole camera traps were operated by 31 trappers, along with ACA staff, on 56 registered traplines during three winters in the Boreal Forest (2013 – 2016; Figure 4). During the inventory, 29% of traplines were surveyed all three winters, 30% were surveyed two winters, and 41% were surveyed in only one winter. The camera traps were effective at detecting a wide range of species and worked particularly well for attracting mustelids (Appendix 2). At least 26 different species were detected (7 bird, 5 weasel, 4 ungulate, 3 canid, 2 bear, 2 felid, 2 squirrel and 1 hare species; Table 1). The most common species (detected at ≥50% of all run poles) were red squirrel and fisher, and the least common carnivores (only detected at one site) were grizzly bear (*Ursus arctos*), cougar and mink (*Neovison vison*). Lynx (*Lynx canadensis*) were also very common, occurring at 49% of sites in the Boreal Forest. The most diverse site had eight different mammal species visit in a single winter.

We observed some interesting behaviours from camera images, including a wolverine sitting on a run pole and feeding while a lynx sat behind the run pole a short distance away; wolverines and lynx or two different wolverines eating bait at the same site within minutes of each other; and family groups of lynx, black bear (*Ursus americanus*) sows with cubs, and wolf (*Canis lupus*) packs; separately, we also photographed pairs of wolverine, fisher and marten eat bait and chase each other around at a site (Appendix 2). In general, canids were reluctant to approach run poles, so the distribution of canids from our camera results is limited. Coyotes (*Canis latrans*) and wolves were cautious, but at one site, a coyote visited and repeatedly hung off beaver bait (Appendix 2). Red foxes (*Vulpes vulpes*) were uncommon but curious visitors at run poles throughout our study (2011 – 2016). Ungulates were generally caught incidentally as they moved through the area, although many individuals, especially moose, appeared curious and approached the run pole and cameras (Appendix 2).

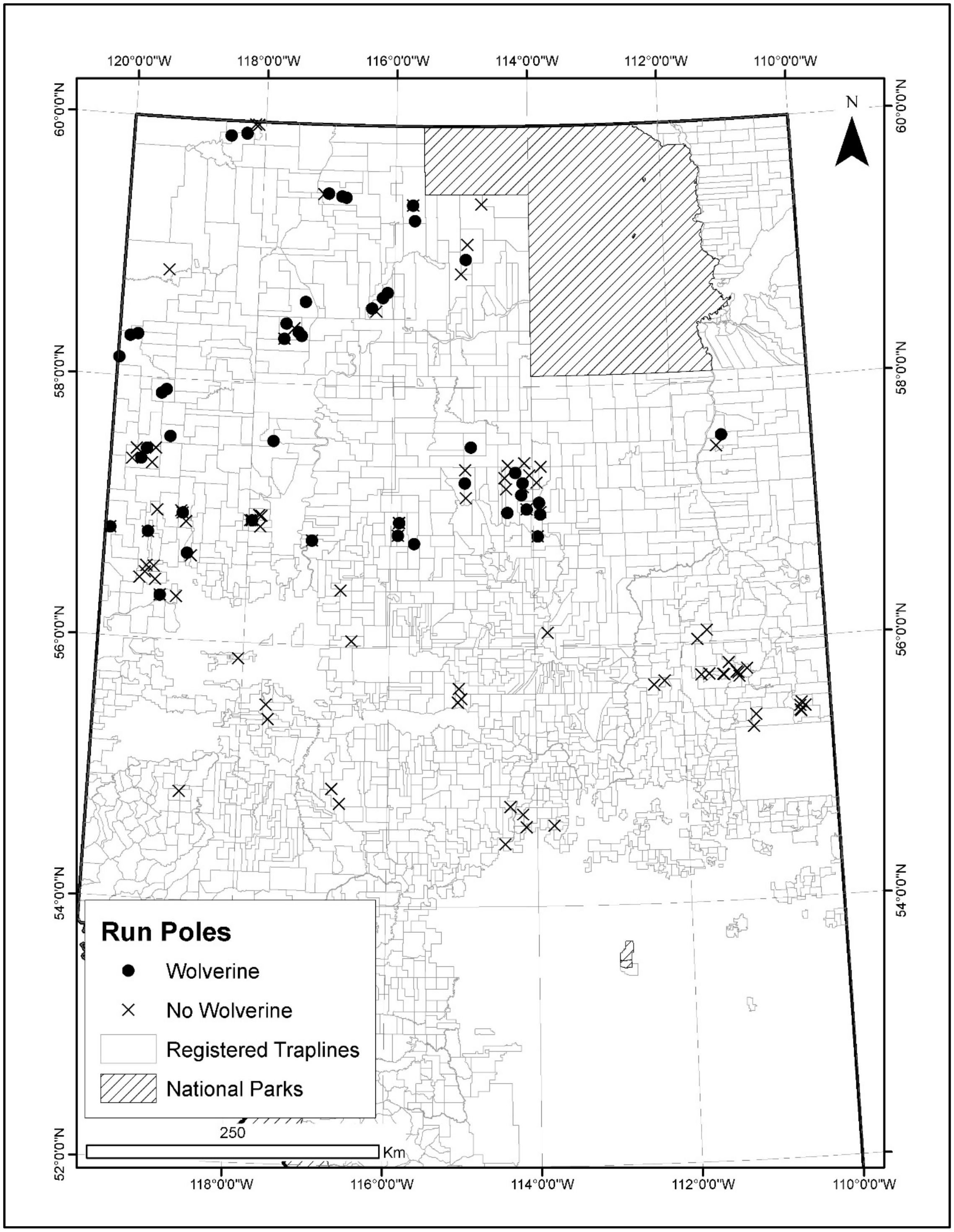

Figure 4. Distribution of sites where wolverines were detected and not detected at run pole camera traps on registered traplines in the Boreal Forest (2013 – 2016).

Wolverine (53% day), lynx (56% day) and fisher (53% day) had slightly more visits in the day (6 a.m. to 6 p.m.) than night (6 p.m. to 6 a.m.), although about 20% of all visits occurred during dawn/dusk for wolverine and lynx. Wolverines seemed to prefer visiting run poles during full moons, as the largest number of visits occurred during this moon phase and few visits occurred during a new moon. We saw a similar trend each winter for the proportion of sites visited by wolverines to peak in late February to mid-March. Similarly, lynx visits peaked in February and March, and fisher visits peaked in March. The individual that spent the most amount of time at a run pole was a male wolverine (W99) located near Rainbow Lake, spending 118 hours from late December 2015 to late March 2016. Males tended to spend more time at run poles than females, but a female wolverine near Thurston Lake spent 56 hours spread over 6 weeks. The particular run pole she visited was also visited by several other wolverines. Two individuals, W1 (male) and W6 (lactating female), were repeat visitors and detected repeatedly from winter 2011/12 to 2015/16 near Rainbow Lake (Appendix 3). Six different wolverines was the maximum number of individuals identified at a single run pole in one winter; this occurred at two sites located near Rainbow Lake and northeast of High Level. These sites occurred on two registered traplines that also had the most wolverines identified throughout our study; we identified 18 different wolverines over 5 winters near Rainbow Lake and 9 different wolverines over 4 winters northeast of High Level.

In total, 56 different wolverines (16 males, 10 females, 30 unknown) were identified at approximately one-third of our study sites in the Boreal Forest from 2013 – 2016 (Appendix 3). Over the course of the study, we identified four lactating females in the Boreal Forest near Rainbow Lake, Birch Mountains and Clear Hills. Most wolverine visits were wolverines climbing and feeding on bait (80%), as opposed to climbing the run pole but not eating the bait (10%) or not climbing the run pole (10%). During three winters, we had six sites where wolverines visited but never climbed the run pole, and in most cases, the wolverine visited once and left the site quickly. However, for five of the six sites, wolverines visited other sites in the general area over the years. The main camera aimed at the run pole captured 509,649 animal images, with one-third of the images being wolverine (2013 – 2016). Visits captured by the camera were measured based on species images separated by at least 1 hour. The main camera was effective at capturing visits for smaller species that spent a lot of time in pursuit of the bait, such as fisher, marten, weasel, red squirrel and flying squirrel. The secondary camera placed at the site further away was better at capturing visits of larger animals that may have passed through the site and did not approach the run pole and/or walked around the site, such as lynx, wolf, coyote, black bear, snowshoe hare, white-tailed deer and caribou.

For wolverines, the number of total visits detected on the main camera and on the secondary camera were similar, but in some cases, the secondary camera detected cautious individuals that did not approach the run pole. Fisher was a common species, and the number of visits and total time spent at run poles were highest for this species. Excluding bears, lynx spent the most time per visit (45 minutes), followed by fisher (35 minutes), wolverine (32 minutes) and marten (20 minutes; Table 2). Interestingly, a similar temperature trend was observed for fisher and lynx visits; 45% of all visits for these two species occurred when the temperature was -9 to 0°C, and only 1% of visits occurred when the temperature dipped down to -30 to -40°C (Figure 5). A similar trend was observed for marten, with 40% of visits occurring when the temperature was -9 to 0°C. In contrast, the greatest proportion of wolverine visits occurred when the temperature was -19 to -10°C (38%), and 4% of visits occurred at -30 to -40. For visits for all species, the most common temperatures measured were -9 to 0°C (40%), yet wolverine activity indicated a preference for colder temperatures. Our results suggest that temperature can affect species' activity and detection trends. Wolverines appeared to be less sensitive to colder temperatures compared with lynx, fisher and marten.

Table 2. Total number of visits, average time of visits and total time spent for select species recorded by the main camera in the Boreal Forest (2013 – 2016).

Species	No. of visits	Avg. time (min.)	Total time (min.)
Fisher	1,779	34.85	62,001
Marten	1,262	20.32	25,644
Squirrel	888	6.18	5,484
Lynx	882	45.01	39,695
Wolverine	625	32.20	20,128
Weasel	573	5.32	3,048
Flying squirrel	85	5.94	505
Wolf	38	9.76	371
White-tailed deer	31	7.65	237
Black bear	26	58.42	1,519
Moose	21	1.90	40
Coyote	20	10.35	207
Red fox	8	10.00	80
Snowshoe hare	8	0	0
Mink	3	0.67	2
Elk	2	11.00	22
Grizzly bear	2	60.50	121
Caribou	1	0	0

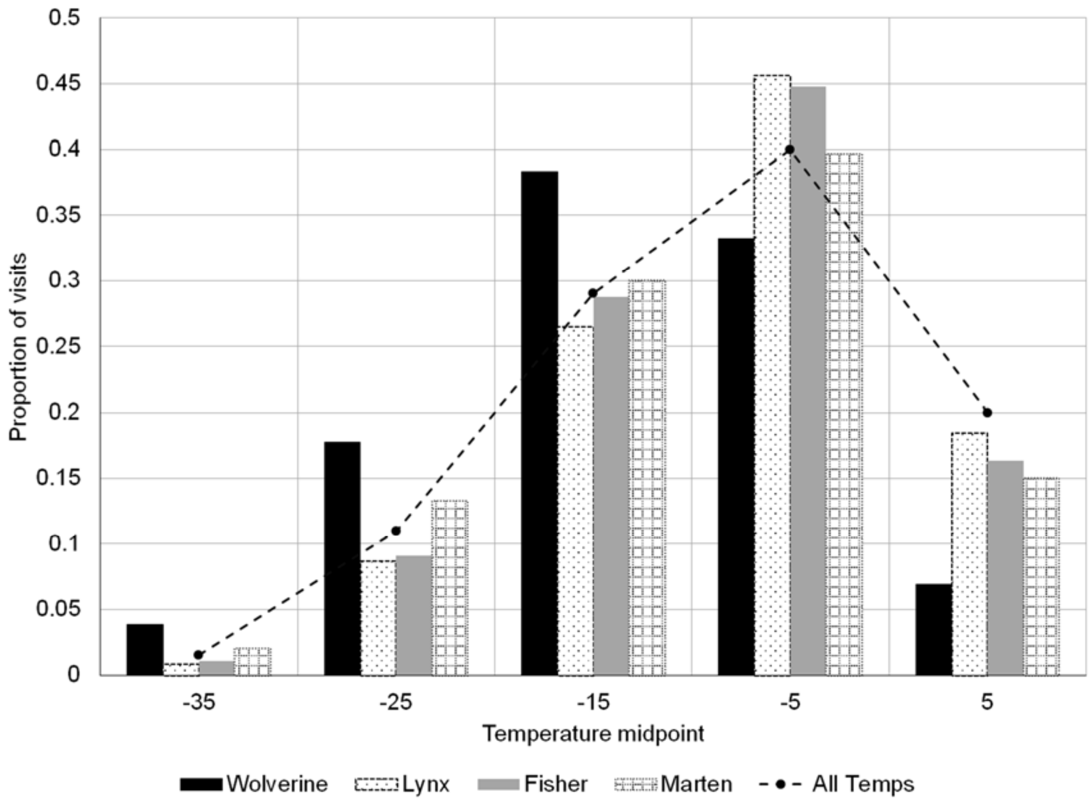

Figure 5. Proportion of visits by temperature (°C) measured at camera traps for wolverine, lynx, fisher and marten in the Boreal Forest (2013 – 2016).

4.2.2 Occupancy Models

Wolverine

We found that wolverines were more likely to occur at more northerly latitudes in the Boreal Forest from 2013 to 2016. We detected wolverines from 56° to 60°N (n = 115 sites), but no wolverines were detected from 54° to 55°N (n = 39 sites; Figure 4). There was a declining trend in occupancy over time (i.e., proportion of sites where wolverines were detected), but we did not sample the same townships and registered traplines each winter, so it was difficult to determine whether this was a population change or simply resulted from surveying different habitats (naïve occupancy 2013/14: 0.51; 2014/15: 0.31; 2015/16: 0.17). Each year, we attempted to fill in geographic holes in our sampling distribution, often in areas further south and with less history of wolverine presence. Initially, volunteers were easiest to engage in areas where they knew with certainty there were wolverines. As such, we expected our naïve occupancy to decline over time as we added these new lower-probability sites. Annual detection rates (i.e., proportion of months that wolverines visited) also fluctuated and were highest when occupancy was lowest (detection 2013/14: 0.52; 2014/15: 0.46; 2015/16: 0.81), but this trend could be due to small sample size. The range and average values of variables measured at sites each winter (Appendix 1) overlapped values from other winters, indicating good variation in habitats surveyed. Early in our study (2011 – 2013), we found that bait quantity was important; when bait was beaver (as opposed to ungulate), larger (half or whole beaver), and more intact, sites had more wolverine visits. For the multi-season occupancy analysis, we only included registered traplines that were surveyed at least two winters (n = 33 traplines) so the survey areas were similar. Latitude was the best variable for predicting wolverine occupancy on registered traplines. We also found that other variables were important in predicting wolverine occupancy: occupancy was negatively associated with density of wells and roads, and positively associated with cooler theoretical temperatures. We found weak support for the remaining variables, but this could be due to small sample size.

When combining all the sites together across years (2013 – 2016), we increased our sample size (n = 98 sites) and determined which variables had the most support for predicting wolverine occurrence. For the variables, only latitude and winter snow depth were strongly correlated: snow tended to be deeper at more northerly latitudes. Wolverine occurrence was positively associated with intact forest, winter snow depth and cooler theoretical temperatures, and negatively associated with density of roads and wells. The top model that best predicted wolverine occurrence included food (conifer, ungulate, wetlands) and climate (winter snow depth) and explained 15% of the variation. Based on run pole results, this model predicted wolverines to occur in areas that had more conifer forest and deeper snow, but less ungulate and wetland habitats. The next best model had some support, predicting wolverines to occur in places that had lower road density, more intact forest with less development, and deeper snow; this model explained 11% of the variation in wolverine occurrence. Overall, it appeared that wolverines were more likely to occur in places that had less development, more conifer forest and cooler climates with more snow.

Based on early results from the Boreal Forest (2013 – 2015), we saw a trend in where wolverines were being detected; they tended to show up in places that were more remote, with fewer roads, more conifer forest and cooler climates. We used our run pole results in 2014/15 (n = 62 sites) to predict where wolverines were likely to occur in the Boreal Forest (Figure 6). Mapping predictions is our best guess of where wolverines are more or less likely to occur based on the relationship between wolverine occurrence and rough proxies for food (conifer forest), climate (temperature index), refuge (distance to towns) and development (roads). Predictive maps are useful for combining multiple variables at once to explore why wolverines occur in some places but not others. An area may get a lot of snow and is far from towns, but has very high road densities and not much conifer forest, which would decrease its suitability for wolverines. We did not sample in Wood Buffalo National Park, but we extended our predictions there given its close proximity to our study area. We compared our predictions to run pole results and found that wolverines were detected in areas that were predicted to have significantly better habitat, indicating that the coarse-scale variables we chose to represent wolverine habitat were adequate. Wolverines were found in habitats with higher probability of occurrence in winter 2013/14 (wolverine $\bar{x}$ = 0.1 ± 0.01 (SE); no wolverine $\bar{x}$ = 0.07 ± 0.01 (SE); t_{45} = -1.98, P = 0.054) and 2015/16 (wolverine $\bar{x}$ = 0.18 ± 0.05 (SE); no wolverine $\bar{x}$ = 0.1 ± 0.02 (SE); t_{43} = -2.08, P = 0.044). The best habitat for wolverines in the Boreal Forest was predicted to be north of 56°N, where road densities tended to be lower, forests were conifer-dominated, and climates were cooler. Wolverines tend to occur in rugged terrain, and we found that wolverines in our study were no exception. We detected wolverines in higher terrain of the Boreal Forest: Cameron Hills, Clear Hills, Caribou Mountains, Buffalo Head Hills and Birch Mountains. But many wolverines were detected outside of these hilly areas and in more typical lowland boreal habitat surrounded by wetlands. High Level has a lot of open land used for agriculture, it is considered a population centre (~3,500 people), and its temperature index was midway between warm and cool, but wolverines frequently visited run poles located near there. Similarly, we would not expect wolverines north of Fort Vermillion based on surrounding habitat, but we observed wolverines at run poles in all three winters. The corridor between Peace River to High Level was not predicted to be excellent wolverine habitat, but some wolverine visits occurred near Manning. We had limited run pole results from northeastern Alberta near Fort McMurray, but it is interesting to note that our models predicted lower likelihood of wolverines in that area due to high road densities and predicted warmer climate than surrounding areas. The run pole results supported earlier findings from fur harvests and trapper questionnaires. Northern Alberta appears to have good wolverine habitat: this area is remote, lacks large cities, and has a cooler climate. Industrial development occurs but wetlands limit summer access, so recreational opportunities on the landscape are more limited, unlike in the Foothills and Rocky Mountains.

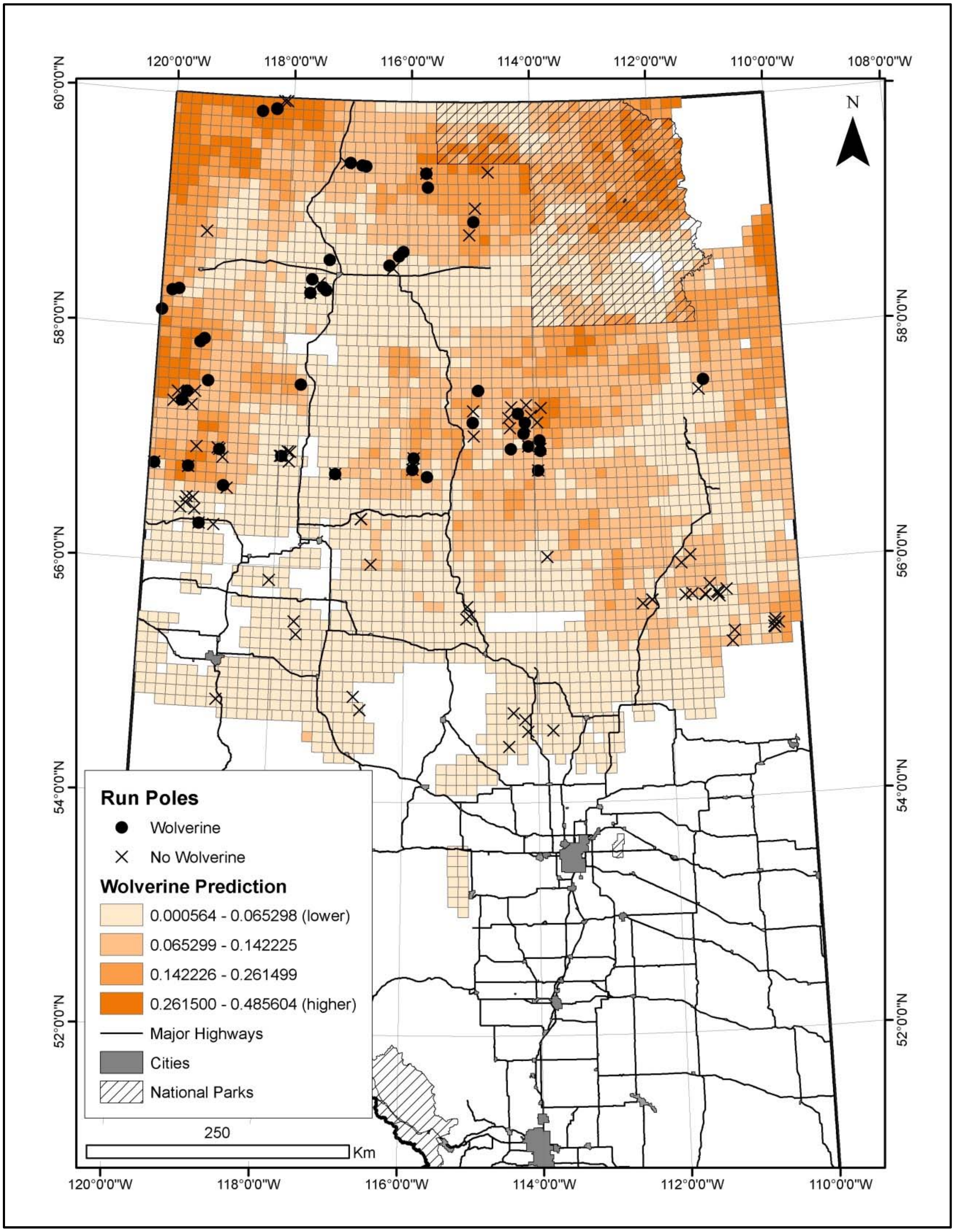

Figure 6. Comparison of areas where wolverines were detected and not detected from 2013 - 2016, relative to predicted occurrence based on township proximity to nearest town, per cent conifer, road density, and temperature index in the Boreal Forest. Darker colours indicate higher probability of wolverine occurrence in a township.

Other species

Lynx had a widespread distribution in the study area (Figure 7), but similar to wolverine, we saw a decline in annual naïve occupancy over the three winters (2013/14: 0.72; 2014/15: 0.48; 2015/16: 0.39). We also found that occupancy declined over time on registered traplines that were sampled at least two winters (n = 33 traplines; 2013/14: 0.52; 2014/15: 0.39; 2015/16: 0.3). The decline could have resulted from the natural ebb and flow of the lynx cycle, from the location of the sites sampled each winter, or the variation in survey effort (March was a good month to detect lynx, but not all sites were surveyed in March in all winters). During the first winter, a high proportion of sites were occupied by lynx, whereas the last two winters were more similar. Rather than focusing on the trend in occupancy, habitat associations where lynx were detected may be more useful. Similar to wolverine, lynx detections were associated with areas that had more conifer forest, less wetlands and deeper winter snow depths. Lynx occurred at all latitudes (54 – 59°N) but appeared to be more common at more northerly latitudes. Conifer forest and winter snow depth were the most important variables in predicting lynx occurrence, accounting for 8% of the variation in lynx occurrence. We did not find any significant associations between lynx and disturbance variables (e.g., roads, wells, intact forest).

Fishers were widely distributed (Figure 8) and very common, and had slightly variable annual naïve occupancy over time (2013/14: 0.54; 2014/15: 0.47; 2015/16: 0.61). We found that fisher occupancy was less variable on registered traplines that were sampled at least two winters (n = 33 traplines; 2013/14: 0.42; 2014/15: 0.51; 2015/16: 0.52). We did not find the big differences in occupancy trends for fisher that we saw for wolverine and lynx, and the habitats where we found fishers also differed. Typically, fishers were associated with areas that had more deciduous forest cover and more shallow winter snow depths, and were located closer to towns. A higher proportion of fishers were located at sites in the lower latitudes (54 – 56°N). As our sampling distribution changed among years (e.g., increased sampling in lower latitudes), we suspect that it became more favourable for observing fishers. We did not find associations between fishers and disturbance variables (e.g., roads, wells, intact forest). We lacked adequate sample size to assess habitat associations for other species.

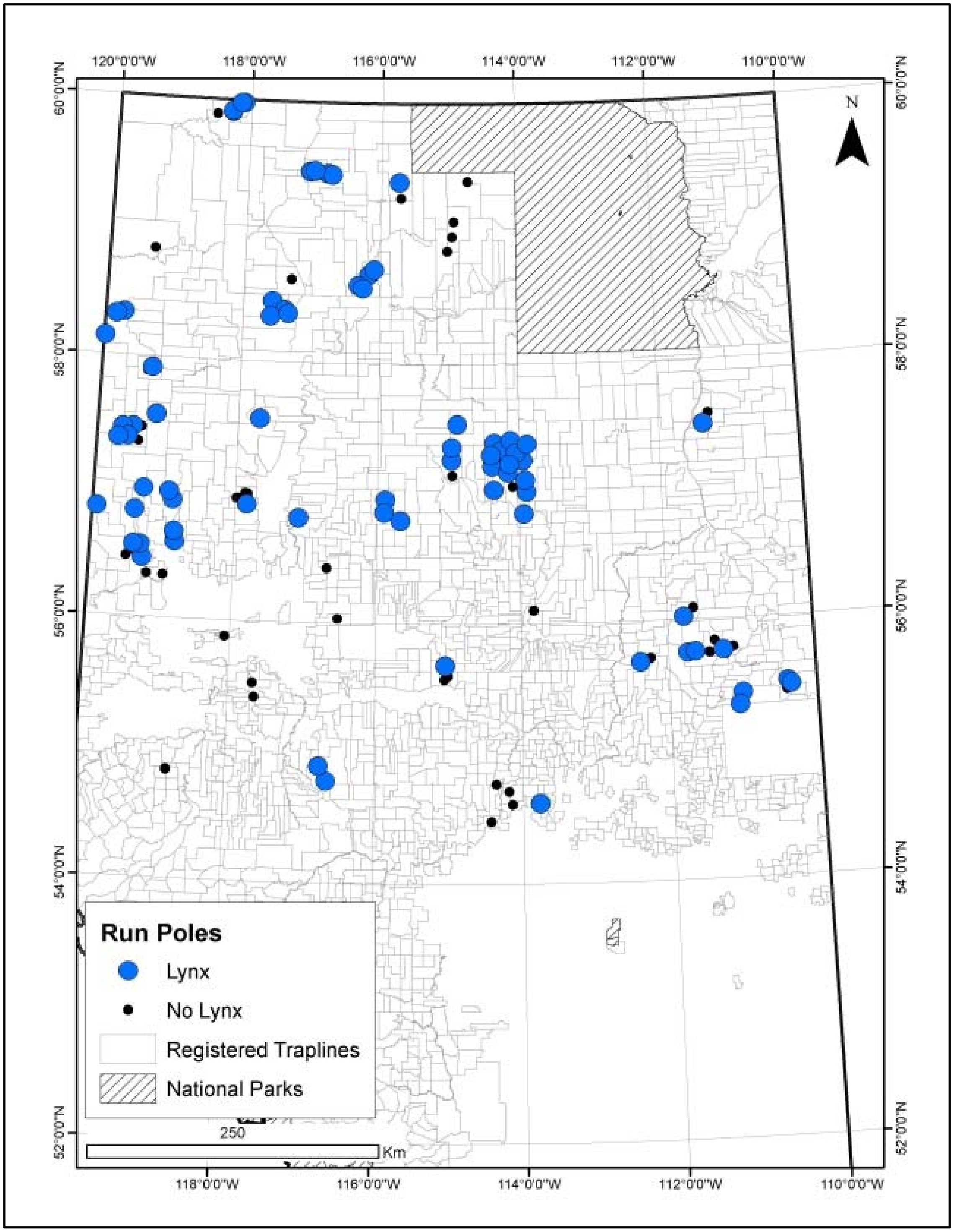

Figure 7. Lynx detected at run pole camera traps in the Boreal Forest (2013 – 2016).

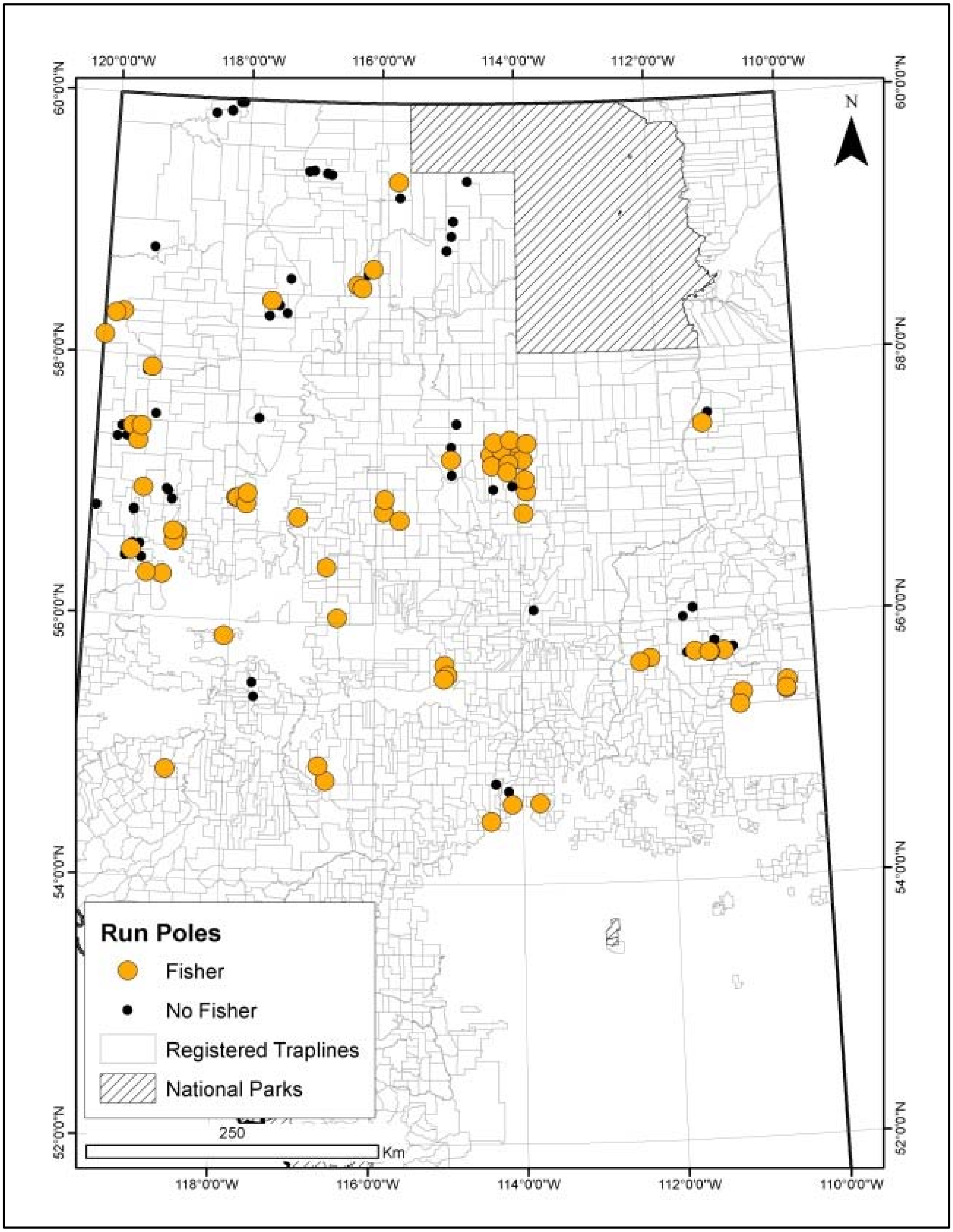

Figure 8. Fishers detected at run pole camera traps in the Boreal Forest (2013 – 2016).

Species interactions

We found evidence that wolverine and lynx detections were not independent in the Boreal Forest (2013 – 2016). Chi-squared tests indicated that the observations of lynx and wolverine occurred more often together than expected. There were few sites where wolverines were detected without lynx, and often biweekly site detections of lynx and wolverine were similar. When a wolverine visited a site, a lynx often visited it within the same time frame. We also found a similar pattern of declining observations of lynx and wolverine throughout our study. During the first winter (2013/14), wolverine and lynx were detected at 38% of all sites, neither was detected at 19% of sites, and 9% of sites had wolverine but no lynx. During the second winter (2014/15), both species were present at 23% of sites, neither was detected at 47% of sites, and 6% of sites had wolverine but no lynx. In the third winter (2015/16), wolverine and lynx were present at 17% of sites, neither was detected at 61% of sites, and there were no sites that had wolverine but no lynx. We have not been able to determine whether that pattern was caused by a simultaneous population change for those two species, a change in the distribution of our sampling locations, or a change in how well we were able to detect the animals that were there (e.g., change in the availability of alternate food sources). We did not find support that wolverine and fisher, or lynx and fisher, observations were related. Surprisingly, we did not find a relationship between fisher and marten detections; observed and expected observations were similar in the Boreal Forest (2013 – 2016). Overall, marten was more common at sites in the Rocky Mountains and Foothills (Table 1), while fisher was more common in the Boreal Forest, although there was a fair amount of overlap between these two species in the Boreal Forest (2011 – 2016; Figure 9). We lacked adequate sample sizes to assess interactions for other species such as felids (Figure 10) and canids (Figure 11).

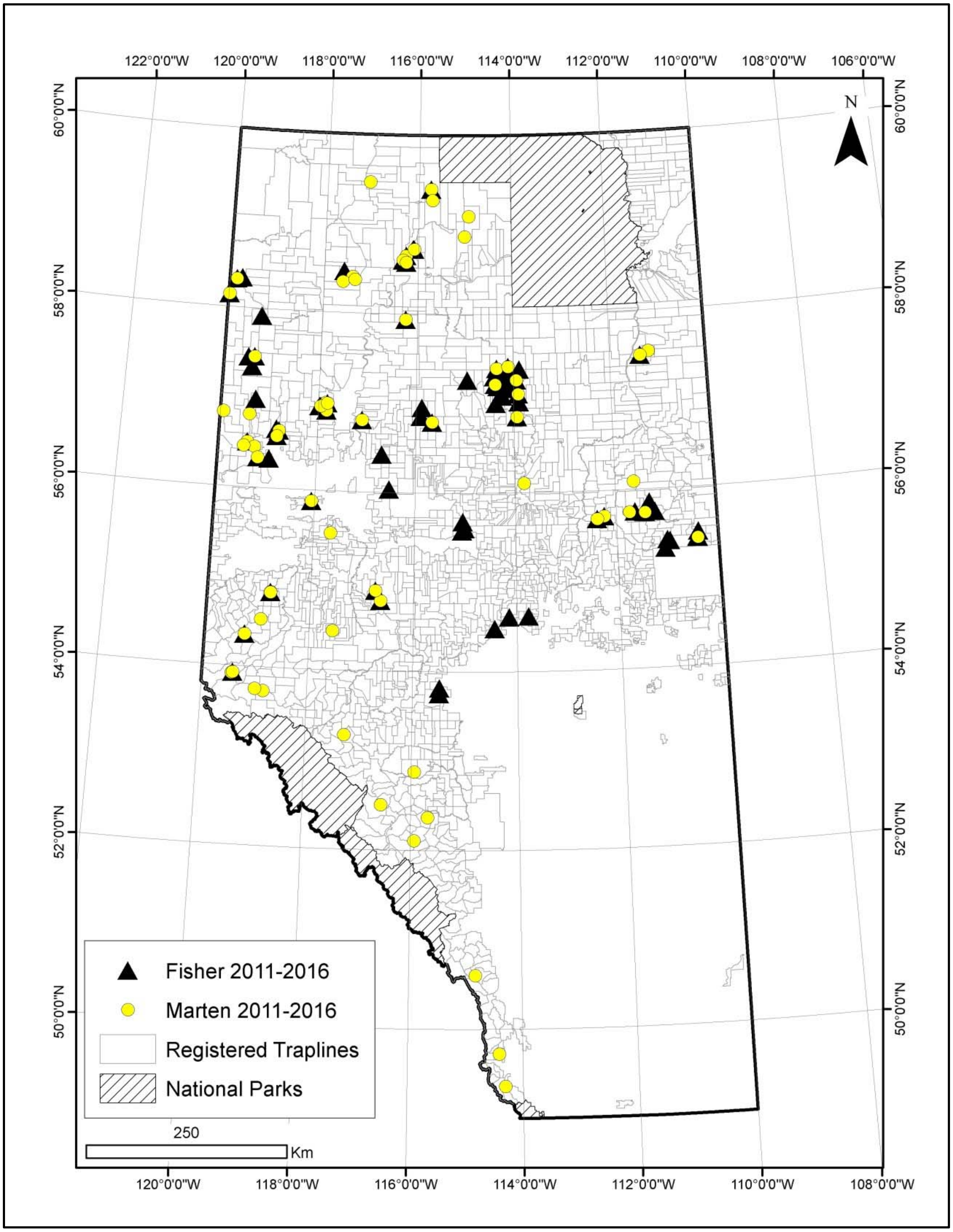

Figure 9. Distribution of marten and fisher detections at run pole camera traps from 2011 – 2016 in Alberta.

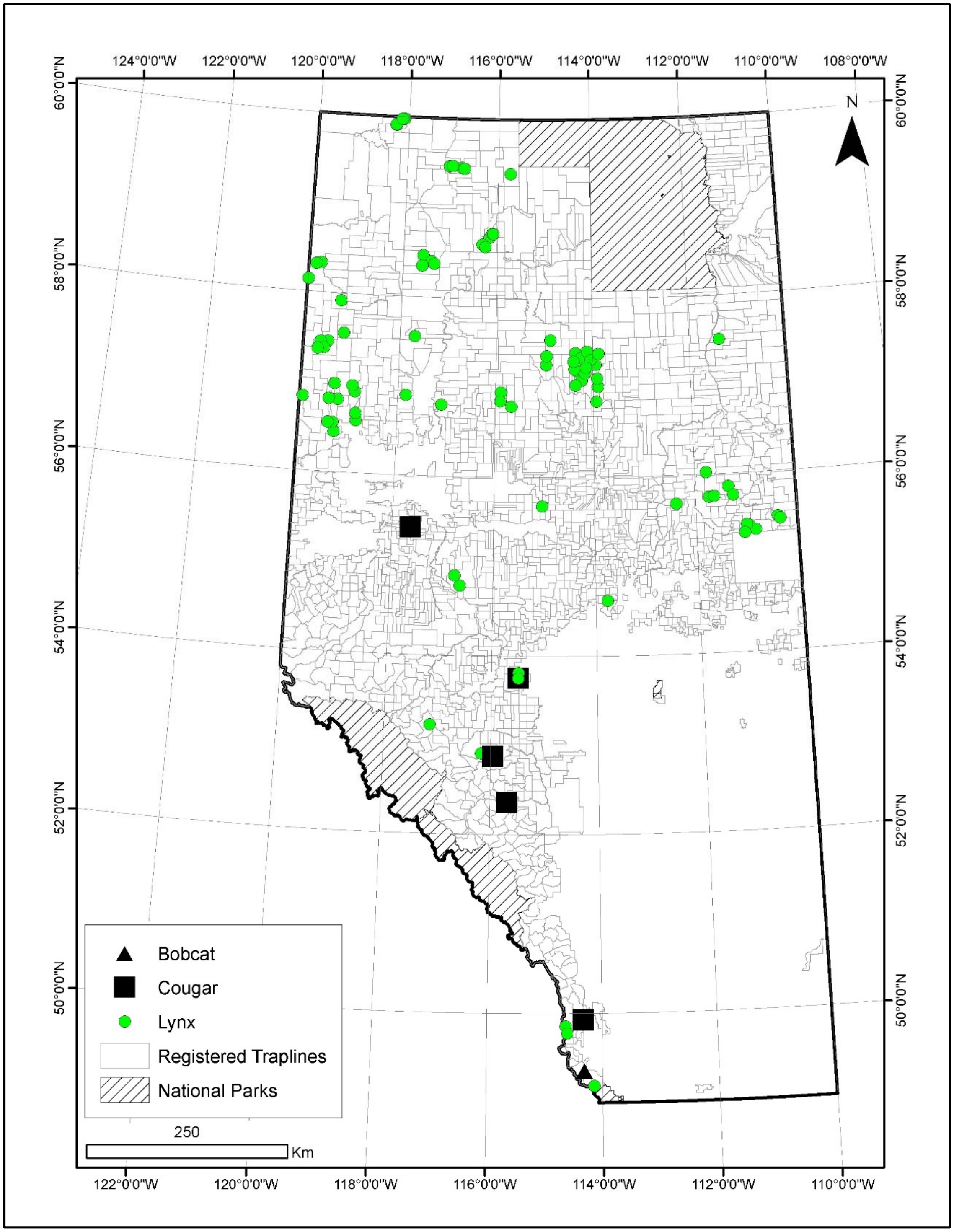

Figure 10. Distribution of bobcat, cougar and lynx detections at run pole camera traps on registered traplines in Alberta (2011 – 2016).

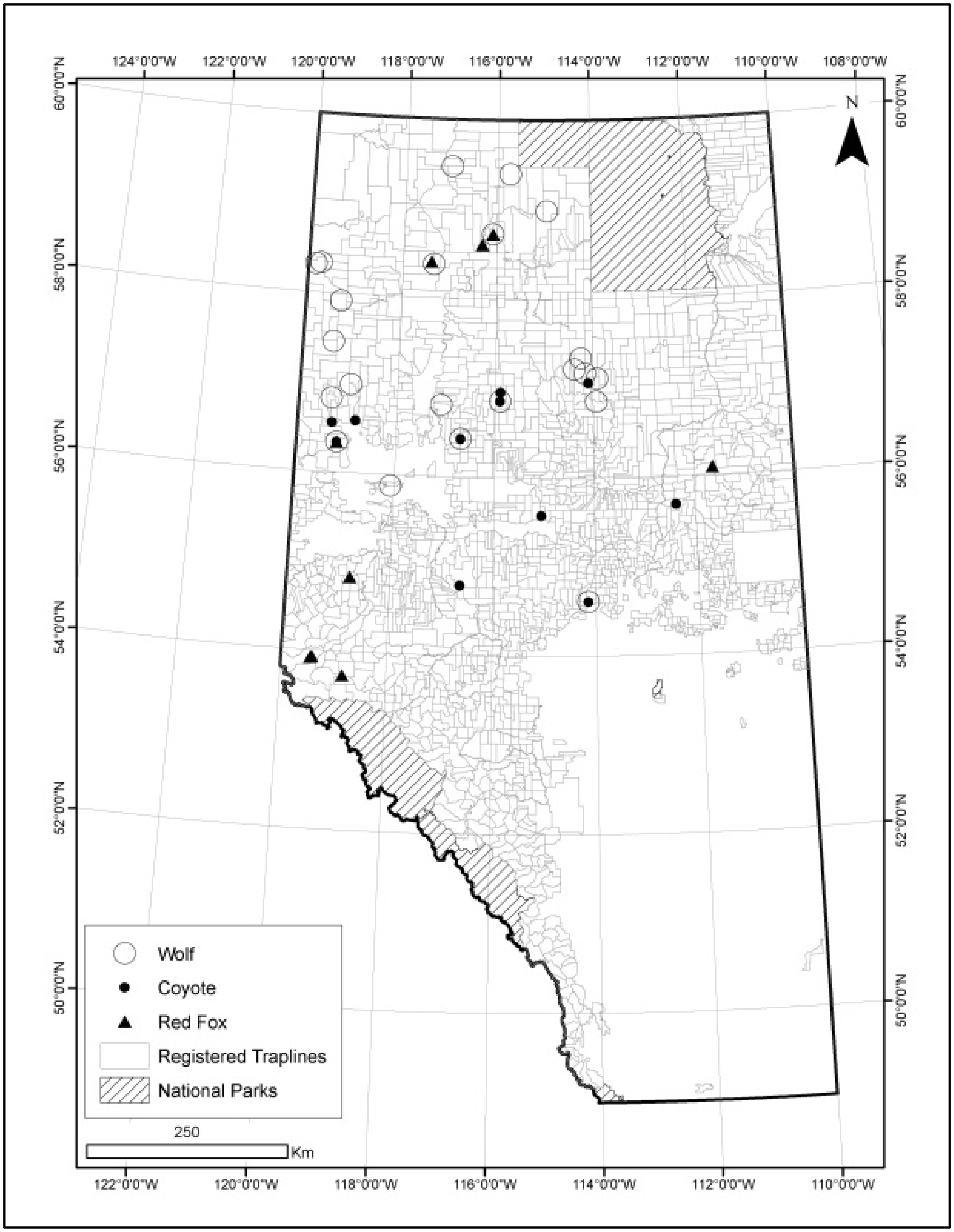

Figure 11. Distribution of wolf, coyote and red fox detections at run pole camera traps on registered traplines in Alberta (2011 – 2016).

4.3 Genetic analysis

The genetic analysis indicated that wolverines had similar haplotypes across the mountains (n = 13 individuals). Wolverines in the Grande Cache area had similar haplotypes to those in the Crowsnest Pass area in southwestern Alberta, primarily "L" (54%), but wolverines in the mountainous areas also had some similarity to wolverines in the Boreal Forest, having some of the ubiquitous haplotype "A" (46%; McKelvey et al. 2014; Figure 12). In a previous study, 47% and 29% of wolverine DNA samples were haplotype "L" and haplotype "A" in the Grande Cache area (n = 17 samples; Cegelski et al. 2006). In the Boreal Forest (n = 70 individuals), haplotype "C" was most prevalent (47%); this haplotype has been found previously in the Cascade Mountains of Washington and southern British Columbia, the Northwest Territories and Nunavut, Saskatchewan, and near Grande Cache (McKelvey et al. 2014). Haplotype "A" was the most dominant wolverine haplotype found in the United States and was also common in our northern Alberta study area (33%). Haplotype "F" identified primarily in northwestern Alberta (also found previously from Nunavut to Alaska) was less common (17%). We also identified the first wolverines with Tomasik "D" in Alberta (3%), an uncommon haplotype in North America but previously found in the Northwest Territories and eastern Saskatchewan (McKelvey et al. 2014; Zigouris et al. 2012). It was common for wolverines at nearby sites to have two different haplotypes. The trapline with the most genetic diversity occurred approximately 50 km east of High Level in northwestern Alberta where four haplotypes (A, C, D and F) were found from 13 individuals. Interestingly, on this trapline, females were also detected and the maximum number of different wolverines at a single site during a winter season in our study (n = 6 individuals) was recorded.

In addition to haplotype, the DNA tests were able to identify gender and differentiate individual wolverines, which allowed us to compare these results with those from the dual approach of using hair and photo analysis. In most cases, photos provided good evidence to determine which wolverine the hair samples came from and its gender. But at sites with multiple wolverines, DNA tests were more effective at teasing apart which individual left which hair sample. Of the 81 wolverines we identified from photos in the Rocky Mountains and Boreal Forest (2011 – 2016), eight were of unknown gender based on photos; however, the DNA analysis was able to identify gender. It was reassuring that the DNA results confirmed that we were correctly identifying gender from photos. Wolverines that spent a lot of time on a run pole were more likely to leave hair samples and to be photographed multiple times, which could be used to identify individual and gender. Roughly half of the wolverines we identified from photos left hair samples that were genotyped. Few samples (22%) lacked adequate DNA for determining gender; fortunately, we still had a good chance of identifying gender for each individual because multiple samples were generally tested from the same individual. So the advantage of using DNA tests is a high probability of determining gender from most of the samples submitted, but not all wolverines left hair samples. The run pole camera trap technique was particularly valuable in differentiating shy wolverines that came into view and had pictures taken of their chests, but did not necessarily leave any hair samples. Gender was more difficult to identify for all wolverines on the run pole, so the DNA results certainly helped fill in some of the gaps. Our results indicate that the run pole set up could be simplified by omitting the alligator clips to collect hair samples, without losing a significant amount of data, depending on the study objectives.

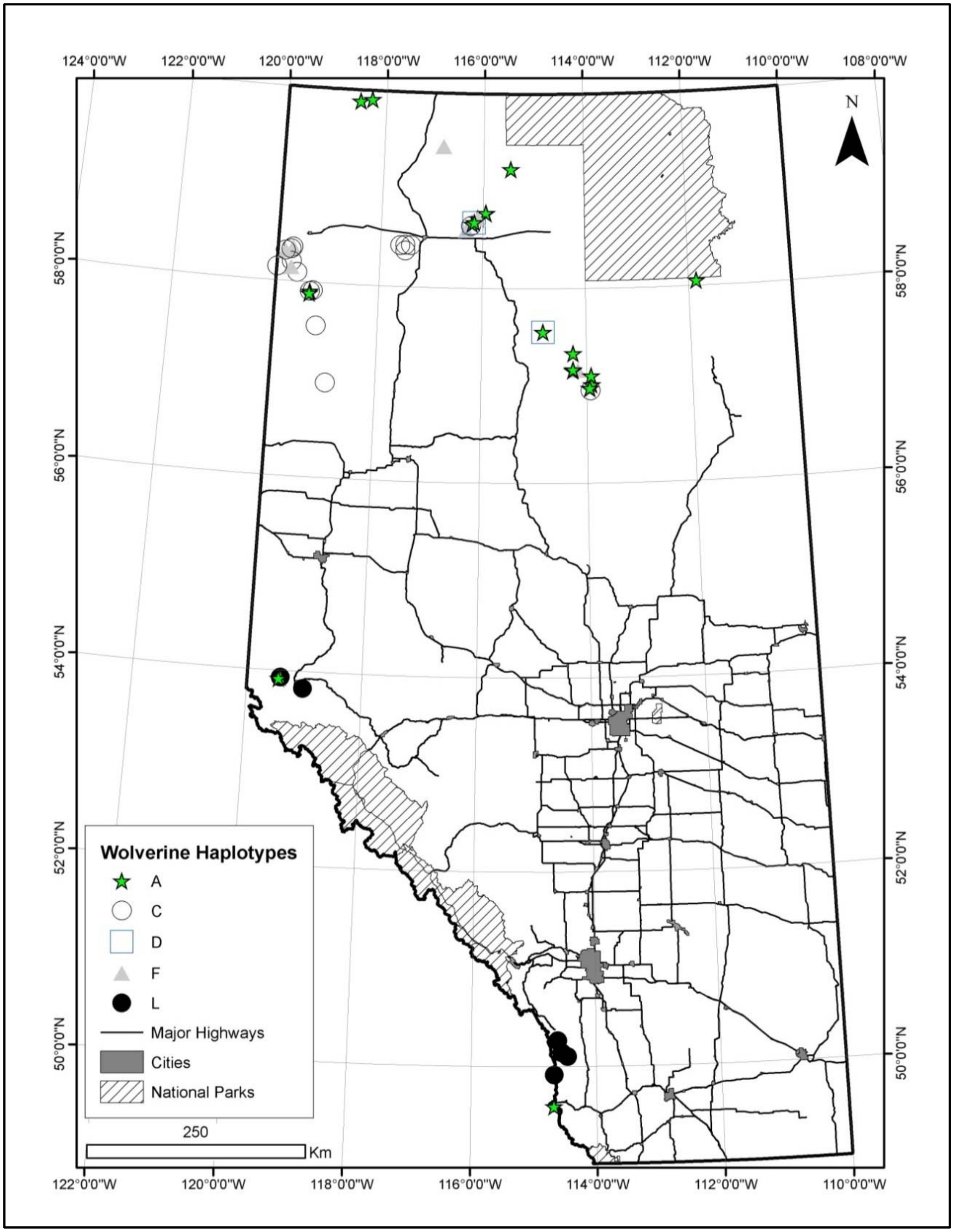

Figure 12. DNA results of wolverine haplotypes identified on registered traplines in Alberta (2011 – 2016).

5.0 FINAL REMARKS

We had two primary goals for this project. First, in a partnership with ATA and others, we wished to use the knowledge of Alberta's trapping community to help assess the population status and habitat needs of wolverines and other furbearers in the province. Second, we wished to help ensure the long-term availability of areas within a working landscape where sensitive species such as wolverines can persist and produce sustainable populations. This report represents the collaborative work undertaken to address the first goal. Our intent is to use this information to help us achieve the second goal.

Our survey revealed interesting findings about wolverine occurrence, habitat associations and behaviours that were obtained using non-invasive camera traps. In many instances, our field results verified previous findings from fur harvest and trapper questionnaire analyses. We were able to identify 56 different wolverines based on unique markings over the three winters in the Boreal Forest. Gender was more difficult to confidently determine from photos because wolverines typically move quickly and do not always pose for a photo; the distance of the main camera to the run pole and background lighting were important factors in obtaining clear photos. Our study was likely the first to identify so many wolverines at a single site: we had two sites with at least six different wolverines near Rainbow Lake and High Level. The sites near Rainbow Lake had visits by at least two different pairs of wolverines, suggesting relatedness and a degree of social behaviour not typically associated with mustelids. Based on discussions with trappers and Fish and Wildlife officers, long-term fur harvest records, and evidence of lactating females found in our study and the University of Alberta study (Scrafford et al. 2017), northwestern Alberta appears to be a productive place for wolverines. The Boreal Forest of Canada provides relatively continuous habitat across vast areas. Latitudes in the far north are more remote and are typically colder with short summers and long winters, which wolverines are well adapted for. Industrial development occurs, but the Boreal Forest lacks the large human population centres that occur further south in the Rocky Mountains and Foothills. Low human populations, the large size of the Boreal (600 km wide in Alberta) and abundant wetlands reduce recreational activities on the landscape. The Boreal Forest of northern Alberta may lack the rugged topography and deep snow that wolverines are typically associated with in the mountains, but what it lacks in rock and snow, it makes up for in water and remoteness. Anyone who has tried to drive an all-terrain vehicle through the boreal landscape in the summer will quickly recognize that it is difficult, if not impossible, to move through this landscape during certain times of the year. Preserving remote areas with a colder climate may be important for the long-term sustainability of wolverines in the province.

In the early part of our study (2011 – 2013), we were able to test run poles in the mountains, foothills, and boreal regions, and we found some interesting behaviours in different areas. Sample size was small, but we did find that wolverines seemed more hesitant to climb the run poles in certain areas. In some places, such as Rainbow Lake and Sheep Creek, wolverines climbed the run pole immediately, whereas in other areas, such as the Birch Mountains, wolverines were much more hesitant, and some individuals never climbed the run pole (Crowsnest Pass). Similar to previous research (Fisher et al. 2013), we never detected wolverines in the Foothills, where predators, people and industrial development were more abundant. Our research efforts provided excellent information on wolverines in the Boreal Forest, but we would need a larger sample size of camera traps in the different natural regions to compare behaviour, habitat, occupancy, etc., of wolverines across the province. Although it is difficult to extrapolate results from the Boreal Forest to other parts of the province, we would expect wolverines to occur in places that are more remote and have cooler climates and more snow.

Run pole camera traps left up until late winter were a useful tool for detecting lactating female wolverines—a good indicator of a healthy, reproducing population. We used image data from run poles and fur harvests to examine the relationship between females and spring snow cover, a variable that has been correlated with the worldwide distribution of wolverines (Copeland et al. 2010, Webb et al. 2016). Females were detected on cameras between February and April in the Rocky Mountains ($n = 4$ females) and Boreal Forest ($n = 8$ females) from 2012 – 2016. The lactating female in the mountains ($n = 1$) overlapped large areas with deep snow that persisted into mid-May. In contrast, the lactating females found in the boreal ($n = 5$) were located far from deep spring snowpack that was patchy, indicating that wolverines were not restricted to areas where snow persisted into late spring. Our study has drawn attention to a lesser-known population of wolverines in northern Alberta and suggests wolverines may be more flexible in their habitat requirements than previously assumed. More research at a finer scale is needed to determine what types of dens are used, how long dens are used, and what role snow plays in creating structure for dens in relation to reproductive success. Our findings show that although spring snow cover was limited for Boreal wolverines, occupancy was higher in areas predicted to have cooler climates and deeper winter snow depths.

Given that wolverines have such large home ranges, an area that is not occupied by wolverines in the winter could be occupied in the summer, and vice versa. We had sites with no wolverine visits during the winter, but then a wolverine appeared in April, May or June. Our results were limited to the winter season, but our methods could be modified to be used in the summer. Lithium camera batteries last a long time in the field; some limiting factors include maintaining bait and accessing wet, remote areas during spring/summer. Non-target species tend to consume bait quickly, but if a strong scent lure is used and a whole beaver is tied up so that it is completely out of sight (ravens) and out of reach (bears), it could still be an effective attractant for a long period of time. The protocol could be simplified by building the horizontal run pole with onsite timber and excluding the hair-snag component. Any trail camera will work to take photos of wolverines that enter the area, but a minimum of two cameras should be used at a site (one camera aimed at the run pole, one camera a little further from the run pole with a wider field of view). As an alternative to using bait, researcher Robert Long from the Woodland Park Zoo in Seattle is testing the use of an automatic scent lure that uses lithium batteries to expel a few drops of skunk scent for up to nine months. Having automatic scent dispensers with some visual attractants (bones, feathers) would be useful for detecting carnivores with minimal effort. We found that the month of March was an excellent time to detect many different wildlife species, but it would be interesting to see how occupancy and detection change across all seasons.

The five wolverine haplotypes (A, C, D, F, L) that our hair samples provided have been previously observed in wolverines from other studies in the western United States and Canada (McKelvey et al. 2014; Zigouris et al. 2012). In the Rocky Mountains of the United States, the dominant haplotype is "A" from 250+ wolverines tested (McKelvey et al. 2014). All of the wolverines sampled from the Cascade Range in northern Washington and southernmost British Columbia were haplotype "C"; they were unique in that they were the only population sampled in the contiguous United States that contained this haplotype (McKelvey et al. 2014). The nearest wolverines reported to have haplotype "C" occur in mid-to-northern Alberta—many of which were part of our study—indicating genetic movement between these populations at some point. It was also interesting to see haplotype "D" detected for the first time in Alberta at two of our sites in the Boreal Forest. The genetics data really shows how connected populations are.

Non-invasive camera traps maintained by trapper citizen scientists were successful at detecting wolverines and many other wildlife species, demonstrating the potential use of cameras in long-term monitoring studies. Working together to plan and implement this trapper-initiated research had mutual benefits for ATA and ACA. Trappers learned about non-invasive methods and new technology used by scientists, increased their trust in wildlife research, and developed a sense of pride in contributing to an effort aimed at filling data gaps that could affect the management of wolverines. From a research perspective, biologists were able to access remote areas, dramatically increase human resources to monitor more sites, acquire ample bait (critical to detecting wolverines and getting them to climb the run pole), and have a dialogue with trappers to learn about how they think the system works and then incorporate these ideas into some of the data analyses. Equally important were the relationships, trust and mutual respect developed as biologists were able to work side by side with trappers and learn about trapping as a tool for wildlife management. This collaborative effort has spurred additional research in northern Alberta (e.g., wolverine radio-collaring studies) and increased our understanding of wolverine ecology, behaviour and habitat associations, which will help inform a future status assessment for this currently *Data Deficient* species. Perhaps most importantly, this citizen-initiated science project has engaged a variety of resource users in a discussion about the types of habitats that need to be conserved to help ensure the long-term sustainability of wolverine populations within a working landscape.

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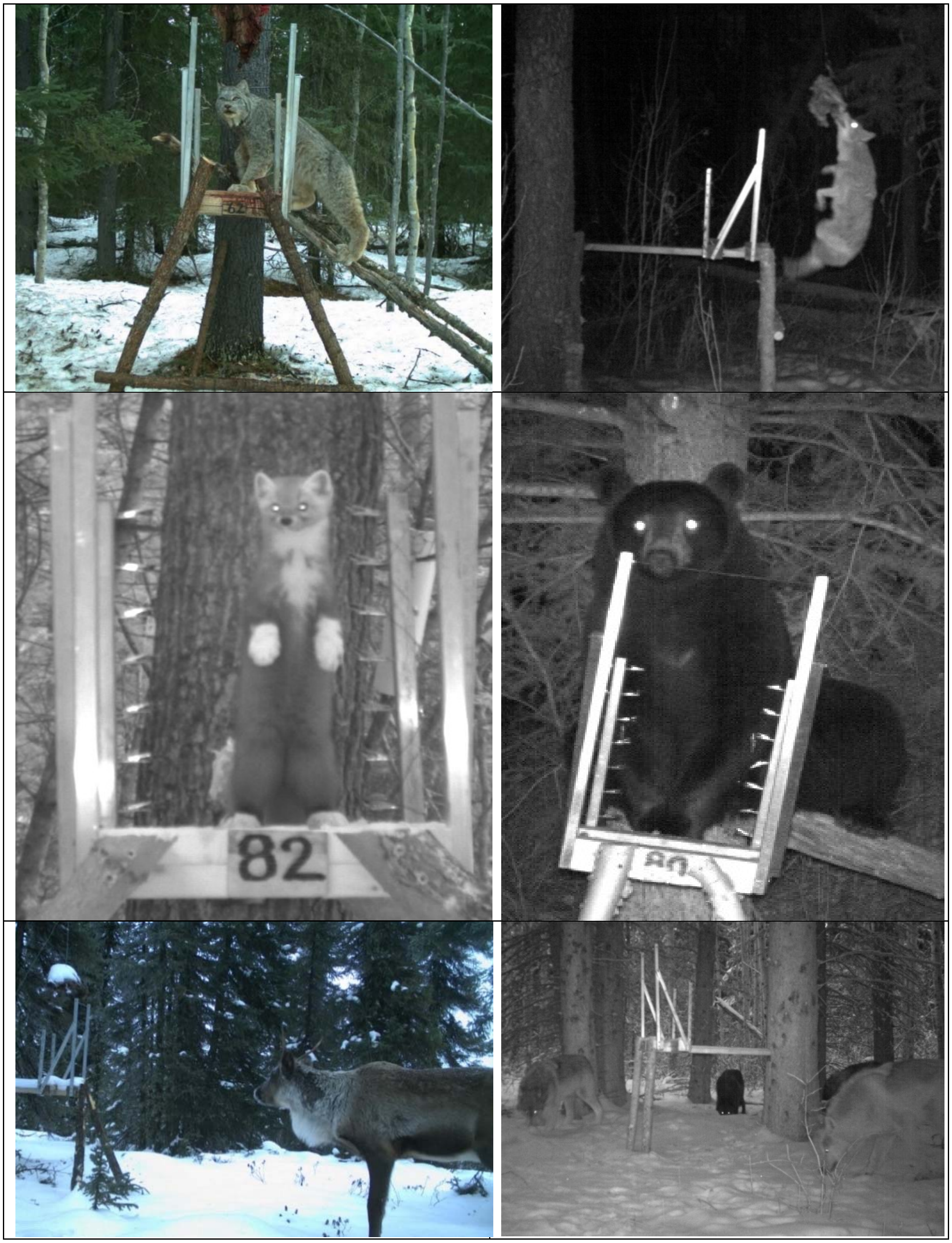
7.0 APPENDICES

Appendix 1. List of variables used to model habitat associations for wolverine, lynx and fisher based on run pole results in the Boreal Forest (2013 – 2016).

Variable	Description
% conifer	Mean per cent conifer forest cover of overlapping townships within 5 km buffer. Source: Alberta Biodiversity Management Institute (Castilla et al. 2014)
% ungulate	Selected good, better and best potential for ungulate habitat with few limitations based on ungulate capability land index; calculated per cent of good–best values for each Boreal township; calculated mean per cent ungulate habitat of overlapping townships within 5 km buffer. Source: Canada Land Inventory, Environment Canada (1972)
% wetland	Selected fen, bog, and open water wetland types to create beaver habitat index; calculated per cent of wetland within 5 km buffer. Source: Alberta Merged Wetland Inventory, Alberta Environment and Parks
% intact forest	Mean per cent intact forest of overlapping townships within 5 km buffer. Intact forests are large, undeveloped contiguous pieces of land. Source: Global Forest Watch Canada (Lee et al. 2010)
Nearest population centre	Nearest distance (km) from site to population centre (towns ≥1,000 people). Source: ESRI
Road density	Mean road density (km/km^2) of all roads (e.g., gravel, paved, truck trail) of overlapping townships within 5 km buffer. Source: Alberta Environment and Parks
Cutline density	Mean cutline density (km/km^2) of overlapping townships within 5 km buffer. Source: Alberta Environment and Parks
Well density	Mean well density (number of wells/km^2) of overlapping townships within 5 km buffer. Source: Alberta Environment and Parks
Temp index	Mean temperature index value based on latitude and elevation of overlapping townships within 5 km buffer. Source: B. Taylor, ACA
% spring snow cover	Mean per cent persistent spring snow (1 – 7 years) of overlapping townships within 5 km buffer. Source: Copeland et al. 2010
Winter snow depth	Calculated mean monthly snow depths (centimetres) from December to March (1998 – 2014) for each Canadian Meteorological Centre (CMC) location; used 10 km buffer around each site to calculate mean snow depth of overlapping CMC locations. Source: CMC, Environment Canada (Brown and Brasnett 2010)

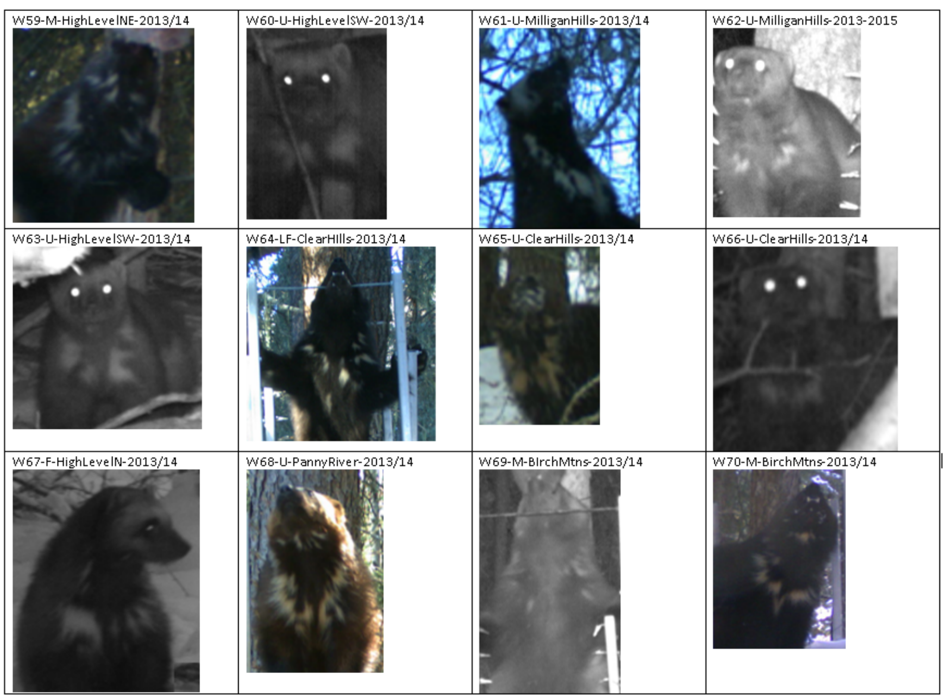
Appendix 2. A wide variety of wildlife species were detected at non-invasive camera traps maintained by trappers in Alberta (2011 – 2016).



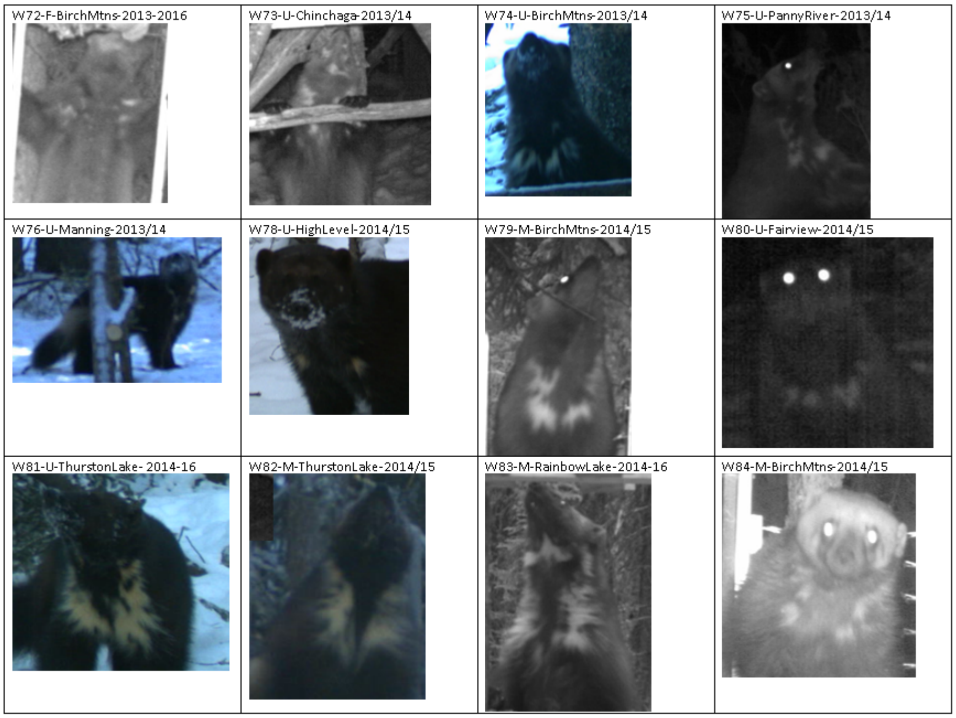
Appendix 2. Continued.

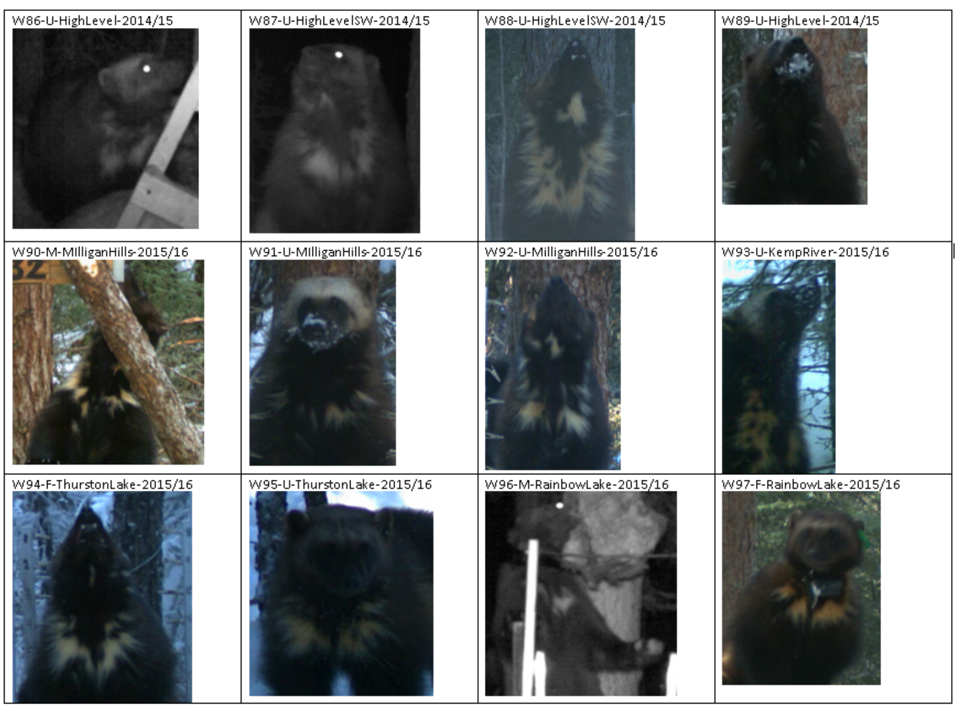
Appendix 2. Continued.

Appendix 3. Individual wolverines identified at run pole camera traps on registered traplines in the Boreal Forest (2013 – 2016). Gender (male [M], female [F], lactating female [LF] and unknown [U]), general area and years detected are noted for each wolverine.

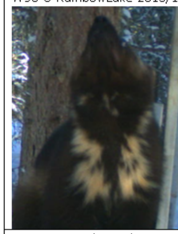
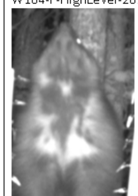


Appendix 3. Continued.





Appendix 3.   Continued.

W98-U-RainbowLake-2015/16 	W99-M-RainbowLake-2015/16 	W100-M-RainbowLake-2015/16 	W101-F-RainbowLake-2015/16 
W102-M-RainbowLake-2015/16 	W103-U-RainbowLake-2015/16 	W104-F-HighLevel-2015/16 	W105-U-Chinchaga-2015/16 

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Alberta Conservation Association