

From: [Grizzle, Betty](#)
To: [John Guinotte](#)
Subject: Updated report from Tony Clevenger - density estimate
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I know you don't have time to read all of this, but thought I would share this latest report that Tony sent me today - they created a density map (**see Figure 3** on page 14) based on spatial capture-recapture modeling. It might be interesting if we to do something similar with the Multi-State occupancy study data. Let me know what you think after you get a chance to review.

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Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

Mapping the Wolverine Way: Identifying conservation corridors and linkages in the Canadian Crown of the Continent ecosystem



Final Report to the Wilburforce Foundation

Prepared by

Anthony P Clevenger, PhD
Western Transportation Institute, Montana State University

Garth Mowat, PhD
British Columbia Ministry of Forests, Lands, and Natural Resource Operations

Mirjam Barrueto, MSc
Wildlife Biologist, Canmore, Alberta

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EXECUTIVE SUMMARY

The Canadian Crown of the Continent (CCoC) is one of three zones where wolverines can move between Canada and the US, providing the last links for recruitment and ultimately gene flow to the highly fragmented population in the US Rocky Mountains. But a combination of rapidly expanding logging, energy development and motorized recreation, along with a growing road network, threatens to fragment and diminish connections in this critical transboundary linkage between the US and Canada.

The province of Alberta recently created two parks in the CCoC expanding protection in the Castle Wilderness north of Waterton Lakes National Park and along the British Columbia (BC)-Alberta border. The western boundary of the Castle is the biologically rich Flathead Valley of BC. The Castle expansion highlighted the need to manage the Flathead to maintain viable wolverine populations and the corridors that keep them connected and transborder connections with the northern US Rockies. However there is limited baseline data on wolverine density, distribution, or gene flow in this critical transboundary area.

In August 2014, the US Fish and Wildlife Service (FWS) withdrew its Proposed Rule to list the distinct population segment (DPS) of the North American wolverine as threatened “due to uncertainty in the science and effects of climate change on their population”. Stated in their withdrawal was recognition that there is good evidence that genetic diversity is lower in wolverines in the DPS than it is in the more contiguous habitat in Canada and Alaska. Further, the effect of small population sizes and low genetic diversity may become more significant if populations become smaller and more isolated.

Wolverines are a conservation priority both provincially and nationally. Wolverines are a species of management focus for BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) due to uncertainty about sustainability of legal trapping and hunting harvest, particularly in the Kootenay Boundary Region. Our work addresses information needs by providing a science-based assessment to inform the management and conservation of wolverines in the CCOC and Columbia Basin.

In 2016 with Wilburforce funding, we completed a 3-year non-invasive sampling effort in the CCoC, which was a key part of a larger 6-year effort that surveyed the central and southern Canadian Rockies. This final year we surveyed the wolverine population in the Elk and Flathead Valleys.

Key outcomes from the project are as follows:

- (1) Deployed 70 sampling sites in 2016, completing a 3-year survey of wolverine populations in the Canadian Crown of the Continent ecosystem (CCoC). A total of 153 sites were sampled between 2014-2016.
- (2) 460 hair samples were sent to Wildlife Genetics International for analysis, assigning 12 individuals (8FM: 4M).
- (3) Wolverines occupied 40% of the grid cells within our 2016 study area. We found a clear pattern of decreasing occupancy from north to south.
- (4) Population density estimates are low compared to adjacent national parks and population estimates from a harvest sustainability analysis conducted in 2007. Density estimates confirm occupancy modeling

results that densities are highest in the northern part of study area (Elk/Cadorna Lakes) and decrease moving south towards the Highway 3 transportation corridor and the US/Canadian border.

(5) In our study area, the number of trap lines currently outnumber the estimated resident wolverine population by a factor of four. The study area intersects with 21 trap lines on the Alberta side, and with at least 62 trap lines on the BC side. On the BC side, each trap line provides for unlimited harvest. In Alberta, trappers are limited to one harvested animal per year. Given the low resident wolverine population, we recommend careful evaluation of this management strategy by both BC and Alberta provincial governments. Our forthcoming harvest sustainability assessment will provide further recommendations on this topic.

(6) The low wolverine density in this critical transboundary linkage area is of concern given the current status of wolverines in the contiguous US and reliance on immigration from Canadian populations.

(7) Understanding the limits of trapper harvest on the long-term persistence of wolverines in the BC Rockies and effectively managing their habitat and the landscape corridors that link them need to be key conservation priorities for both BC and Alberta governments and coordinated in a transboundary, international framework.

2016 Final Report to the Wilburforce Foundation

Mapping the Wolverine Way: Identifying conservation corridors and linkages in the Canadian Crown of the Continent ecosystem

BACKGROUND

In February 2013, the US Fish and Wildlife Service (FWS) proposed to list wolverines in the contiguous United States as threatened under the Endangered Species Act. However, in August 2014, the FWS withdrew its Proposed Rule to list the distinct population segment (DPS) of the North American wolverine as threatened “due to uncertainty in the science and effects of climate change on their population”. The FWS withdrawal was based on new information and further analysis of existing and new data. Stated in their withdrawal also was recognition that there is good evidence that genetic diversity is lower in wolverines in the DPS than it is in the more contiguous habitat in Canada and Alaska. Further, the effect of small population sizes and low genetic diversity may become more significant if populations become smaller and more isolated.

The Canadian Crown of the Continent (CCoC) is one of three zones where wolverines can move between Canada and the US, providing the last links for recruitment and ultimately gene flow to the highly fragmented population in the US Rocky Mountains. But a combination of rapidly expanding logging, energy development and motorized recreation, along with a growing road network, threatens to fragment and diminish connections in this critical transboundary linkage between the US and Canada.

The province of Alberta recently created two parks in the CCoC expanding protection in the Castle Wilderness north of Waterton Lakes National Park and along the British Columbia (BC)-Alberta border. The western boundary of the Castle is the biologically rich Flathead Valley of BC. The Castle expansion highlighted the need to manage the Flathead to maintain viable wolverine populations and the corridors that keep them connected and transborder connections with the northern US Rockies. However there is limited baseline data on wolverine density, distribution, or gene flow, or the effects of trap-related harvest on their long-term population viability to inform decision-making aimed at conserving wolverines in this critical transboundary area.

In 2016, we completed a 3-year non-invasive sampling effort in the CCoC (Figure 1), which was a key part of a larger 6-year effort that surveyed the central and southern Canadian Rockies. This final year we surveyed the wolverine population in the Elk and Flathead Valleys.

Our 2016 objectives were the following:

1. Complete a 3-year survey of wolverine populations in the Canadian Crown of the Continent ecosystem (CCoC), using non-invasive genetic sampling methods (in itself part of a broader 6-year study)
2. Develop occupancy models of wolverine distribution in the Flathead and Elk Valleys and CCoC
3. Use spatial capture-recapture (SCR) models to estimate wolverine abundance and assess the sustainability of wolverine harvest in the BC Rocky Mountains.

4. Determine landscape permeability and identify dispersal corridors for wolverines based on occupancy and spatially-explicit population models from genotyped individuals
5. Provide outreach and communication support to management agencies and other stakeholders.

Ultimately we will collate and share this much-needed science-based information to provide land managers in Canada and across the border in the US with the support they need to make key decisions that can protect critical wolverine habitat.

STUDY AREA

The 2016 study area was located in the Canadian Crown of the Continent (CCoC) ecosystem in southeastern BC and focused in two main areas: the Elk and Flathead Valleys (Figure 2). The 2016 study area was the last of a 3-year sampling grid to survey, situated between two important national parks complexes: Banff-Yoho-Kootenay to the north and Waterton-Glacier to the south. The southern extent of the 2016 grid was positioned on the Canadian-US border. Study sites in 2014 were situated in the Alberta Rockies from the US-Canadian border (Waterton Lakes National Park) to south boundary of Kananaskis Country. In 2015, sampling took place in BC north of Highway 3, west of the Elk Valley to the Columbia Trench and south boundary of Kootenay National Park. Study areas and sites sampled during all three years represented a wide range of biophysical attributes, landscape conditions and levels of human disturbance.

METHODS

We surveyed wolverine occurrence using a systematic sampling design consistent with our previous wolverine research to enable data pooling and large-scale analyses. We overlaid a 12 x 12 km grid on the study area. In each grid cell we placed a sampling site consisting of a hair trap and remote camera aimed at the hair trap. Hair traps consisted of a whole skinned beaver carcass nailed to a tree and secured with baling wire (Fisher and Bradbury 2014). Barbed wire was wrapped from the carcass to ca. 1 m above ground level. Sites were set up during the first month (January 2016) and revisited three times at monthly intervals to rebait, collect hair samples and service cameras. Three replicate monthly surveys were conducted within each survey year to incorporate detectability into occupancy estimates.

We deployed 57 sampling sites over an area of 8208 km² and set an additional 13 sites to increase the number of individual detections for modeling wolverine abundance. Overall a total of 70 sites were set.

RESULTS

Data Collection

Out of the 70 sampling sites, 26 sites (37%) had confirmed wolverine photo-detections and a total of 51 confirmed visits by wolverines (Figure 2). Of a total of 194 monthly sampling sessions during 2016, wolverines visited the sampling sites 26 times (13%). Wolverines were never detected at 63% (n=44) of the sites.

We collected 1311 hair samples during the three monthly sampling sessions. Hair samples were obtained at 80% of 51 sites with confirmed visits by wolverines (n=41). A total of 448 hair samples were sent to Wildlife Genetics International (WGI) for analysis.

Occupancy

Wolverines occupied 40% of the landscape we surveyed in 2016. Previous estimates of occupancy in the Canadian Rockies were 88% in the Banff-Yoho-Kootenay park complex and 36% in Kananaskis Country (Table 1). Our 2014 survey in the Waterton Lakes-Crowsnest Pass area had one of the lowest estimates of occupancy in the Canadian Rockies to date at 17%.

When compared to sampling in our Rockies study area the last three years, wolverine occupancy was greatest in our 2016 BC study area, but varied markedly through space. Similar to our summary results in 2015, we found a clear pattern of decreasing occupancy from north to south. The results from our 2016 survey reinforce the pattern of occupancy we observed in the CCoC last year. This north-south gradient in occupancy mirrors reported wolverine occurrence in the Columbia Mountains (Hausleitner and Kortello 2014, Kortello and Hausleitner 2015). Here a notable decline in wolverine detections occurred from north to south in both the Selkirk and Purcell Mountains in addition to evidence of low genetic connectivity between the south Purcell population and other populations in southeastern BC. These findings are noteworthy given the Columbia and Rocky Mountains are two of the three remaining areas where wolverines and other wide-ranging carnivores can move between Canada and the U.S.

Genetic analysis

All genetic samples (hair and scat) were analysed by Wildlife Genetics International (WGI; 2016 samples) and USFS Rocky Mountain Research Station (RMRS) in Montana (2010-2015 samples). A total of 460 hair samples from 2016 survey were sent to WGI for analysis. The lab identified a total of 138 good wolverine hair samples and genotyped 12 individuals (8FM: 4M).

In December 2015, however, we discovered that the RMRS laboratory, which had analysed all of our 2010-2015 samples, had made substantial genotyping errors with our 2013 samples. This led to the misidentification of a number of wolverines. On close inspection of microsatellite genotypes and spatial/temporal patterns of individual captures we found laboratory errors (that were confirmed by the RMRS upon re-analysis). Consequently, the original 64 wolverines identified from 2010-2013 collapsed to 49 unique individuals. This unexpected incident has caused a significant delay in completing two manuscripts and delayed reporting final results to the Wilburforce Foundation and other funders, land/natural resource managers, and stakeholders (trapping associations, industry, conservation NGOs).

Abundance and density estimates

We use spatial capture-recapture (SCR) models to estimate wolverine abundance and assess the sustainability of wolverine harvest in the Kootenay Region of BC. We determined mark-recapture encounter histories from individuals genotyped during our 2014, 2015 and 2016 surveys in the CCoC. The models produced a density estimate for all three years of 0.78 wolverines/1000km² (CI: 0.496 - 1.23). The expected number of wolverines for the study area including the buffer area is 28.04 wolverines. These results are preliminary, but we don't expect the numbers to change dramatically. Population density estimates for our 2016 study area are low compared to adjacent national parks (Glacier-Waterton Lakes; Banff Yoho Kootenay) and central and northern Selkirk and Purcells.

Our SCR modeling confirms the earlier occupancy modeling results: densities are highest in the northern part of our 2016 study grid (Elk Lakes, Cadorna Lakes area) and densities become progressively lower moving south into the study area towards Highway 3 (Figure 3). Densities then start to increase again

towards the US-Canadian border (and Glacier National Park). The large area between the northern and southern extents of the study area where densities are very low, suggests low levels of connectivity. This “density trough” is aligned with the Highway 3 transportation corridor. The effect of the corridor on connectivity is not known, however, it is a filter barrier to grizzly bear connectivity (Proctor et al. 2012) and we suspect the same for wolverines. We are continuing to work on SCR modeling in the study area as part of the trapper harvest sustainability analysis. These models will be more robust and provide greater clarity with regards to varying wolverine densities throughout the CCoC.

The low wolverine density in this critical transboundary linkage area is of concern given the current status of wolverines in the contiguous US and reliance on immigration from Canadian populations.

DISCUSSION

The Canadian Rockies has been identified as a potential corridor for wolverine movement into the US (Schwartz et al. 2009) and the most likely long-term prospect for transboundary wolverine habitat connectivity given climate change scenarios (Copeland et al. 2010). The results we present are preliminary; nonetheless our data summary suggests lower populations than expected and lower connectivity between the US-Canada border and populations to the north. Lower wolverine occupancy estimates in the southern/transboundary regions compared to those in the central Columbia and Rocky Mountains may be a result of habitat quality and/or human disturbance on wolverine distribution and abundance.

In our study area, the number of trap lines currently outnumbers the estimated resident wolverine population by a factor of four. The study area intersects with 21 trap lines on the Alberta side, and with at least 62 trap lines on the BC side. On the BC side, each trap line provides for unlimited harvest, meaning that within the trapping season, each trapper may take any number. In Alberta, trappers are limited to one harvested animal per year. Given the low resident wolverine population, we recommend careful evaluation of this management strategy by both provincial governments. The forthcoming harvest sustainability assessment will provide further recommendations on this topic.

Several wolverine researchers have previously recommended the creation of refugia, such as those created by protected areas like the Banff-Yoho-Kootenay and Waterton-Glacier national park complexes or restricting or eliminating trapping quotas – as a crucial element in the overall conservation of wolverine (Weaver et al. 1996, Krebs et al. 2004). Due to the large home ranges of wolverines and their low density, an effective conservation strategy will require large areas managed at both regional and transboundary metapopulation scale. Similar transboundary management schemes have been developed for other wide-ranging carnivores in the past (Proctor et al. 2012).

SCHEDULING AND NEXT STEPS

Due to the genotyping errors in previous samples obtained from surveys in the Canadian Rockies we have been unable to meet our scheduled completion dates for objectives 3 (harvest sustainability) and 4 (landscape permeability and dispersal corridors). We are currently working on the first objective and expect to be completed in summer 2017. This will produce the first density estimates of wolverines in the CCoC ecosystem. As part of this analysis, our wolverine density estimates will inform management of wolverine harvest to ensure long-term persistence and viability of wolverines in one of the last remaining linkage zones with populations in the transborder Northern Continental Divide Ecosystem.

We will soon begin work on objective 4 - applying the SCR method across a gradient of human land-uses and landscape characteristics in the CCoC to assess potential impacts on wolverine spatial distribution, abundance and landscape connectivity. We expect that work to be completed in late 2017 or early 2018.

COMMUNITY ENGAGEMENT, EDUCATION AND OUTREACH

We communicated the results of our wolverine survey and research project in a variety of media types and venues.

1. Public presentations

Municipal District of Bighorn – Living in the Natural Environment series (Feb 2016), *Between Rock and Hard Places: Wolverines in Multi-use Landscapes of Alberta* (T Clevenger).

2. Social media

Facebook – This year we created a Facebook page for WolverineWatch.org. The objective was to use this to inform and raise awareness of wolverine conservation, management and research in the Canadian Rockies. Our opening post received more than 29,000 views (posting a video of a wolverine in suburban Lethbridge). We continue to post regularly, including a recent post from our 2016 wolverine survey photograph of a cougar mother with three kittens at one of our hair traps. The posting went viral, receiving more than 1.5 million views.

Instagram - Like Facebook we opened up an Instagram account (Wolverine_Watch) to raise awareness of wolverine conservation and our research in the Canadian Rockies. During our winter 2016 field season we posted regularly, nearly daily, documenting the research, how data are collected, the landscape surveyed for wolverines, and some of frustrations of relying on snowmobiles for travel. We continue to post regularly and currently have over 150 followers.

3. Traditional media

Highline Magazine (Bow Valley). “Gluttons for punishment”, 15 Dec 2015
<http://highlineonline.ca/mapping-the-wolverine-way/>.

ZDF Television, Germany - Documentary about Waterton-Glacier National Parks. Film crew spent one day with us filming fieldwork and field data collection. Hour long documentary was broadcasted by ZDF TV on Christmas eve 2016.

Canadian Geographic – Article on wolverines in western North America and Crown of the Continent ecosystem, prepared by Fraser Los, photographs by Kyle Hamilton. Both Fraser and Kyle spent time in the field with us to help prepare their December 2016 article.

BBC Earth – “The Truth About Wolverines”, an online article by Niki Wilson that highlighted our work on behavioural aspects of wolverines' response to anthropogenic stressors that garnered global attention. <http://www.bbc.com/earth/story/20150421-the-truth-about-wolverines>.

4. Scientific Publications

Steenweg, R., M. Hebblewhite, R. Kays, J. Ahumada, J. Fisher, C. Burton, S. Townsend, C. Carbone, M. Rowcliffe, J. Whittington, J. Brodie, J.A. Royle, A. Switalski, A.P. Clevenger, N. Heim, L. Rich. 2017. Scaling up camera traps — monitoring the planet's biodiversity with networks of remote sensors. *Frontiers in Ecology and Environment* 15: 26-34.

Stewart, F., N. Heim, A.P. Clevenger, J. Paczkowski, J. Volpe, J. Fisher. 2016. Wolverine varies spatially with anthropogenic footprint: implications for conservation and inferences about declines. *Ecology and Evolution* 6:1493-1503.

The sustainability of human-caused mortality of wolverine in southeast British Columbia. *In prep.* Mowat, G., AP Clevenger, D. Hausleitner, A. Kortello, M. Barrueto.

Genetic connectivity and demographic fragmentation of wolverines in the Canadian Rocky Mountains. *In prep.* Sawaya, Clevenger.

Wolverine density in the Canadian Rocky Mountain Parks. *In prep.* Barrueto, Sawaya, Clevenger.

PROJECT PARTNERS

This project is a collaborative effort and we have been working with a number of agencies and organizations to undertake it. Activities are coordinated by the Principal Investigator. A summary of roles is included below:

- **Alberta Environment and Sustainable Resource Development:** Provides in-kind support (GIS support; 60 cameras).
- **BC Ministry of Forest, Lands and Natural Resource Operations:** Provides funding, in-kind support and helps with logistics.
- **Montana State University:** Provides grant administrative support.
- **Teck Coal:** Provides housing in study area.
- **Wildsight BC:** Provides grant administrative support and citizen science involvement in field data collection.
- **Yellowstone to Yukon Conservation Initiative:** Provides grant administrative support.
- **2016 funders:** Cross Foundation (Montana), Volgenau Foundation, BC Fish and Wildlife Compensation Program (Upper Kootenay Ecosystem Enhancement Program), Columbia Basin Trust, Wilburforce and Woodcock Foundations.
- **Other funding support:** US Fish and Wildlife Service Great Northern Landscape Conservation Cooperative, Disney Conservation Fund, Alberta Conservation Association, the Wolverine Foundation and McLean Foundation.

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FIGURES

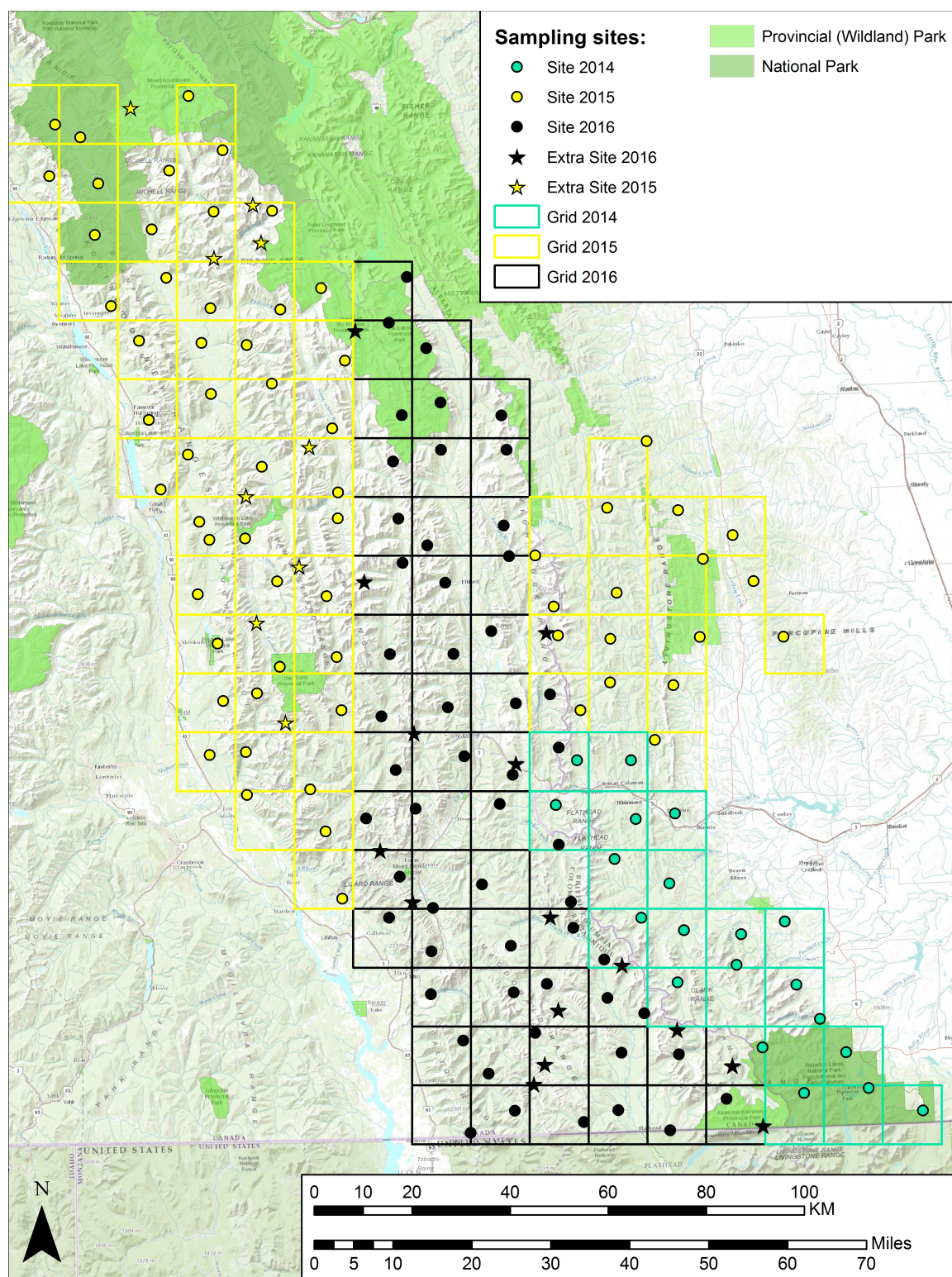


Figure 1. Three study area grids (12 x 12 km) and location of 162 sampling sites for wolverine occurrence in the Canadian Crown of the Continent, 2014-2016.

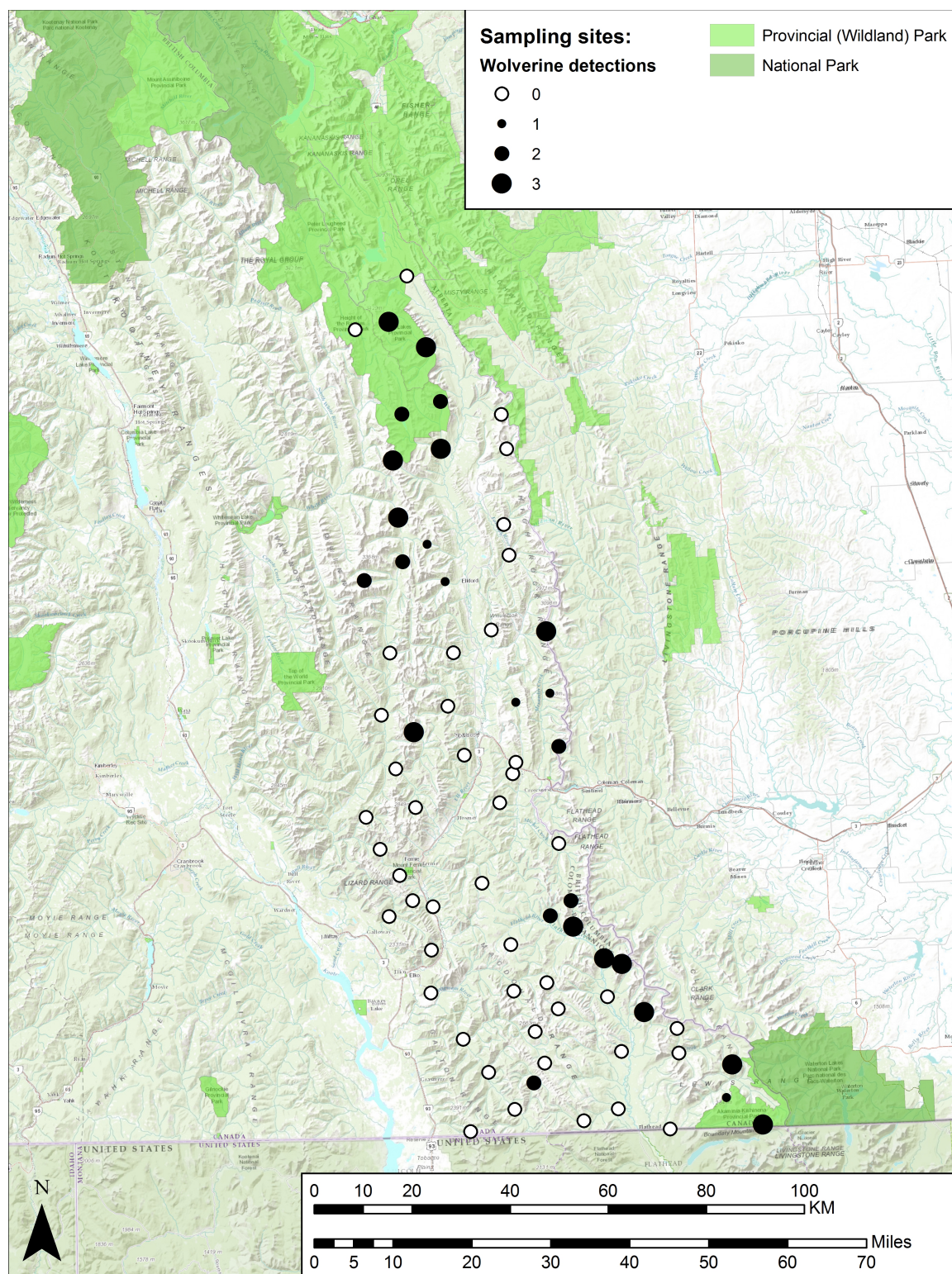


Figure 2. Location of 70 sampling sites and frequency of wolverine detections in the Elk and Flathead Valley study area, Southern Canadian Rockies, 2016.

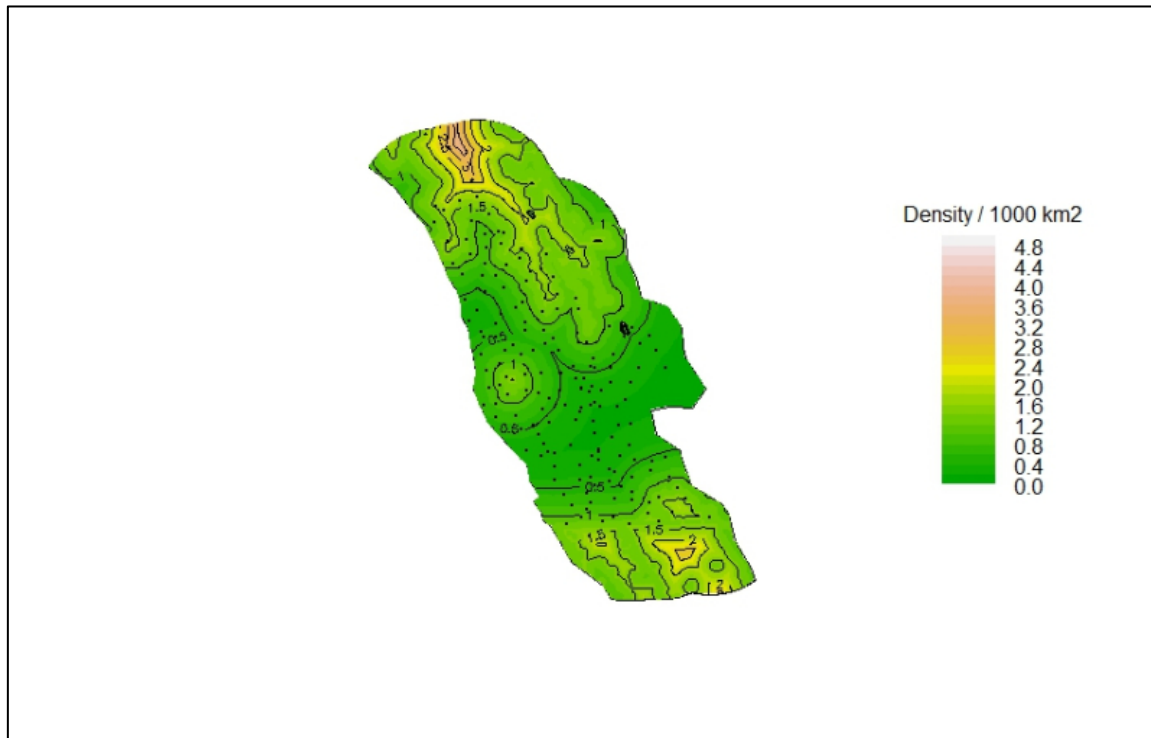


Figure 3. Estimated density surface for 2014 - 2016 study area.

TABLES

Table 1. Estimates of wolverine occupancy (Ψ) with standard error (SE) and confidence intervals (CI) from the Rocky and Columbia Mountains.

Mountain range	Ψ	se ²	CI ³	Naïve ⁴	Reference
Rocky Mountains					
BC – 2016	0.40	0.06	0.29 - 0.52	0.39	This study
Canadian CoC – 2014-2016	0.32	0.04	0.25 - 0.40	0.30	This study
BC – Alberta 2015	0.25	0.05	0.15-0.38	0.23	Clevenger et al. 2015
Waterton-Crowsnest 2014	0.17	0.09	0.05-0.45	0.08	Clevenger, unpubl. data
Banff-Yoho-Kootenay ¹	0.88	0.05	0.72-0.95	0.79-0.84	Clevenger and Barrueto 2014
Kananaskis Country ¹	0.36	0.11	0.12-0.56	0.25	Fisher and Heim 2012
Willmore Wilderness	0.91	0.04	na	0.89	Fisher et al. 2013
West-central Alberta	0.14	0.07	na	0.11	Fisher et al. 2013
Glacier NP, Montana	na	na	na	0.25	Waller, unpubl. data
Columbia Mountains					
Valhalla and South Monashees	0.56	0.46	na		Kortello and Hausleitner 2015
South Selkirks	0.55	0.13	na		Hausleitner and Kortello 2014
South Purcells	0.38	0.10	na		Kortello and Hausleitner 2013
Purcells	0.71	0.10	0.05-0.45		Kortello and Hausleitner 2012