8609242

Public Interest Defense Center, P.C.

P.O. Box 7584 Missoula, Montana 59807

Tel: (406) 531-8133 Fax (406) 830-3085
publicdefense@gmail.com

January 13, 2020

Chief, USDA Forest Service
201 14th Street SW
Washington, D.C. 20250

Secretary, U.S. Department of Agriculture
1400 Independence Ave., SW
Washington, D.C. 20250-0003

Secretary, U.S. Department of the Interior
1849 C Street, NW
Washington, D.C. 20240

Director, U.S. Fish and Wildlife Service
1849 C Street, NW
Washington, D.C. 20240

RE: 60 Day Notice of Intent to Sue under the Endangered Species Act - Elk Smith Project on the Helena Lewis & Clark National Forest

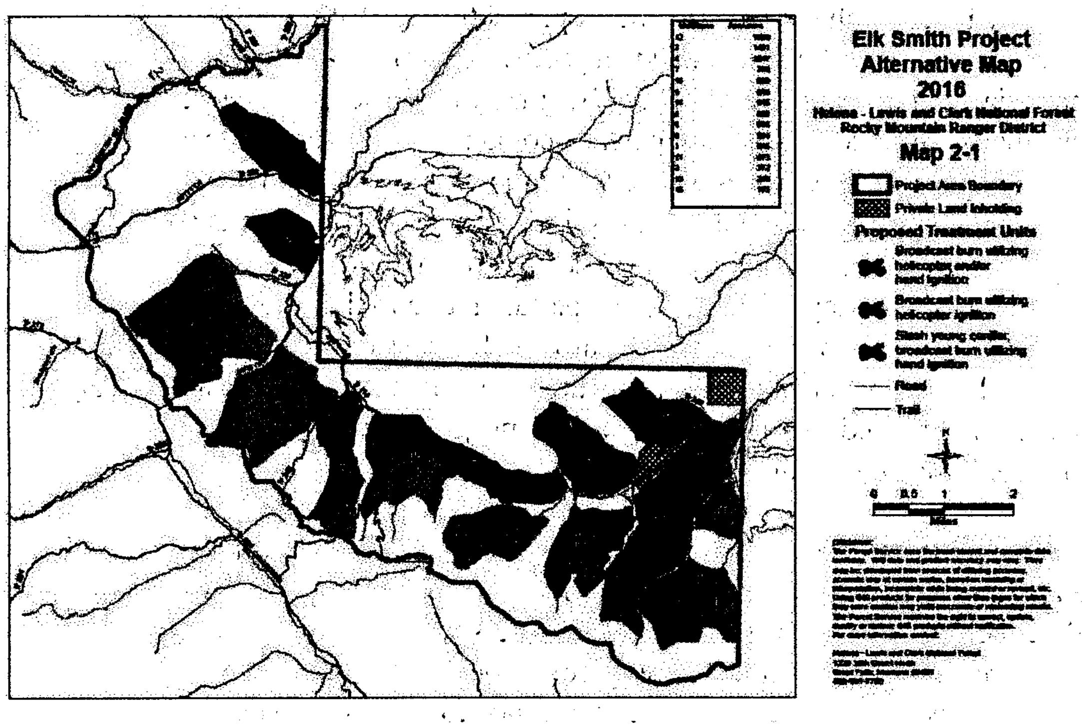
You are hereby notified that Alliance for the Wild Rockies and Native Ecosystems Council intend to file a citizen suit claim pursuant to the citizen suit provision of the Endangered Species Act (ESA), 16 U.S.C. § 1540(g) for violations of the ESA, 16 U.S.C. § 1531 et seq. Alliance will file the claim after the 60 day period has run unless the violations described in this notice are remedied. The name, address, and phone number of the organization giving notice of intent to sue are as follows:

Michael Garrity, Executive Director	Sara Johnson
Alliance for the Wild Rockies	Native Ecosystems Council
P.O. Box 505	PO Box 125
Helena, Montana 59624	Willow Creek, MT 59760
Tel: (406) 459-5936	Tel: (406) 579-3286

The name, address, and phone number of counsel for the notifier are as follows:

Rebecca K. Smith, Attorney at Law
Public Interest Defense Center, P.C.
P.O. Box 7584
Missoula, MT 59807
Tel: (406) 531-8133

On November 1, 2019, Michael A. Muñoz, District Ranger for the Rocky Mountain Ranger District, Helena - Lewis & Clark National Forest signed a Decision Notice authorizing the Elk Smith Project on the Helena - Lewis & Clark National Forest. Project activities have not yet commenced. The Project involves cutting and burning vegetation on 10,331 acres. The majority of the prescribed burning – Units 3 - 6, 8, 10, and 12-15 (totaling 7,744 acres) – will be accomplished with helicopters. The helicopter burning units (green and brown) will be located at higher elevations than the hand-ignition units (purple):



All

10,331 acres of the Elk Smith Project fall within the Bear-Marshall-Scapegoat-Swan Inventoried Roadless Area boundary. Directly west of the Project area is the Bob Marshall Wilderness Complex. Listed and proposed species that may be present in the Project area include grizzly bears, lynx, and wolverines. The Project area is located in MS-1 grizzly habitat within the Northern Continental Divide Ecosystem Grizzly Bear Recovery Zone. The Forest Service Biological Assessment determined that implementation of the Elk Smith Project is *likely to adversely affect* lynx, lynx critical habitat, and grizzly bears. The U.S. Fish and Wildlife Service (FWS) issued a biological opinion in October 2019. Neither the Project Biological Assessment nor the Project Biological Opinion addresses wolverine. In the Project NEPA analysis, the Forest Service stated that the Project will not jeopardize the wolverine. FWS did not issue a letter of concurrence for this conclusion.

Helicopters will cause an adverse effect on grizzly bears. In the grizzly bear Incidental Take Statement, FWS states: "the Service has defined harm of grizzly bears in terms of adverse habitat conditions caused by repeated helicopter flights over a short period of time. The potential use of helicopters for up to five consecutive days per unit, for 10 units, may interfere with the normal behavior patterns of a grizzly bear and may result in adverse effects to an individual grizzly bear that may be using the area during helicopter activity." FWS states: "helicopter activity may displace individual grizzly bears from key habitat to the extent that significant under-use of habitat by grizzly bears occurs. The Service maintains that such under-use of key habitats could result in a female bear's failure to obtain adequate food resources and reduce fitness, impairing its normal reproductive potential. Some adult female grizzly bears wary of humans and human-generated disturbance (e.g. from helicopters) may not breed at their potential frequency or may fail to complete gestation due to decreased fitness." In the Biological Opinion, FWS notes: "in areas of wilderness or areas of low road densities and human developments, the disturbance may be greater because grizzly bears are less habituated to human activity. The project area is primarily non-motorized, thus disturbance may be greater."

As noted above, the Project Biological Assessment and Biological Opinion fail to include any analysis of wolverine. Instead of analyzing wolverine and issuing a jeopardy conclusion in the Project Biological Assessment as required under the ESA, the Forest Service issued a jeopardy conclusion in the Project NEPA analysis. FWS did not issue a letter of concurrence for this conclusion as required under the ESA. In the Project NEPA analysis, the Forest Service included two paragraphs of discussion and then concluded that the Project would not jeopardize the wolverine. The NEPA analysis fails to disclose female dispersal habitat and male dispersal habitat in the Project area, and fails to address the impacts on wolverines from helicopters.

The federal agencies have issued numerous NEPA analyses in the past that acknowledge that wolverines are likely to be displaced from helicopters in a manner similar to grizzly bears. For example, the Forest Service itself has found that wolverine displacement is likely from helicopters involved in logging (Snow Talon EIS, excerpts attached), helicopters involved in dam maintenance (Canyon/Wyant EIS, excerpts attached), and helicopters involved in helicopter skiing (Kenai Heli-ski EIS, excerpts attached).

In particular, the Helena National Forest has previously found that "[h]elicopter overflights could, however, disturb or displace individual[] [wolverines] from adjacent denning and foraging habitat during winter operations" and "summer helicopter operations do have some potential to disturb or displace foraging individual[] [wolverines]." The Chugach National Forest found: "Denning females could be displaced by helicopter skiing activities occurring in denning areas and could abandon their den sites. Myrberget (1968) mentions four instances of den abandonment due to human disturbance and suggests that secondary dens may be less suitable. Direct contact occurred with two denning females in Idaho in late April and May and resulted in den abandonment in both cases (Copeland 1996). Abandonment of den sites would adversely impact both the female wolverine and her kits."

Thus, similar to grizzly bears, the best available science indicates that the use of helicopters for multiple days in a row over thousands of acres of roadless and otherwise undisturbed habitat is likely to adversely affect wolverines and could potentially have a permanent displacement and/or abandonment effect on wolverines. This is an "effect of the action" that must be addressed in the Project ESA consultation, either in the Biological Assessment and/or the Biological Opinion. The agencies' failure to address the effects of the action, and failure to apply the best available science, regarding the impacts of helicopter-based burning over thousands of acres violate the ESA. The agencies cannot tier to any other analysis to account for this failure because no other analysis addresses the effects of the Project, including likely helicopter displacement on thousands of acres, on wolverine. Moreover, the Inman model identifies four types of wolverine habitat – maternal habitat, denning habitat, female dispersal habitat, and male dispersal habitat – and the project analysis only included the first two types, which is a further failure to apply the best available science and fully address the effects of this project on wolverine.

Instead of conducting an analysis of the effects of the action in the Project ESA consultation, the agencies rely on a 2014 programmatic consultation. As the Forest Service states in its objection response letter:

> Response: As noted by the objector, effects to the wolverine were not analyzed in the project BA. However, it was noted in the BA that the "Effects of the project on wolverine (Gulo gulo luscus), a species proposed for listing, was conducted under the 2014 Programmatic Biological Assessment for the North American Wolverine (USDA Forest Service 2014b, USDI Fish and Wildlife Service 2014b)."
>
> . . .
>
> The FWS provided a letter of concurrence in response to the programmatic BA (project file doc: F1_155). . . . Of all the factors described in the programmatic BA, climate change is the only primary threat. Other activities (including prescribed fire) were determined not a threat.
>
> . . .
>
> The objector suggests that the Forest Service did not use the best available science in its analysis of impacts on wolverine . . . . The information used in the analysis includes research from 2010 (Copeland et al.) and 2013 (Inman et al.) that were used to aid in quantification of wolverine habitat in the project area and to clarify the importance of high elevation areas for wolverine. In addition, the 2014 programmatic BA utilized the best available scientific information provided by the Proposed Rule to list the wolverine. . .

The 2014 programmatic biological assessment is premised entirely on the 2013 Proposed Listing Rule: it does not cite any scientific literature in support of its conclusions, but instead simply cites to the 2013 Proposed Listing Rule. In turn, the 2013 Proposed Listing Rule represented that "[f]ew effects to wolverines from land management actions such as grazing, timber harvest, and prescribed fire have been documented." The 2013 Proposed Listing Rule was issued on February 4, 2013 and did not consider any published scientific literature issued after 2012. Thus, the programmatic biological assessment does not even consider, much less apply, any scientific research published after 2012.

Over the past 8 years, new research on wolverines has been published that undermines the agencies' original assumptions. For example, in August 2013, a new published, peer-reviewed scientific journal article was issued that disproves the assumptions. The article published in the Canadian Journal of Zoology found:

> We surveyed wolverines at 120 sites along a natural and anthropogenic gradient using hair trapping and noninvasive genetic tagging. We used abundance estimation, generalized linear, and hierarchical models to determine whether abundance and occurrence was best predicted by natural land cover, topography, footprint, or a combination. Wolverines were more abundant in rugged areas protected from anthropogenic development. **Wolverines were less likely to occur at sites with oil and gas exploration, forest harvest, or burned areas**, even after accounting for the effect of topography. The relative paucity of wolverines in human-impacted portions of this range edge suggests that **effective conservation requires managing landscape development**, and research on the proximal mechanisms behind this relationship.

Fisher et al. 2013. Wolverines (Gulo gulo luscus) on the Rocky Mountain slopes: natural heterogeneity and landscape alteration as predictors of distribution. Can. J. Zool. 91: 706-716 (2013)(attached). Accordingly, the agencies can no longer in good faith ignore the impacts on wolverine from oil and gas exploration, forest harvest, or burning. The agencies are obligated to conserve the wolverine, and to do that effectively requires "managing landscape development," not ignoring it and pretending it poses no threats to wolverines.

Additionally, extensive on-the-ground wolverine tracking efforts in the Helena - Lewis and Clark National Forest have disproven the Copeland model's assumptions of wolverine habitat, which were adopted by the 2013 Proposed Rule and thus adopted by the programmatic biological assessment:

> Wolverine expert Jeff Copeland once defined wolverine habitat as being from 200m above to 200m below timberline. We estimated timberline to be approximately 8,400 feet in the Ogden Mountain to Nevada Creek Region, based upon peaks along the nearby Continental Divide and in the Scapegoat Wilderness. We then analyzed 246 wolverine location data points (wolverine tracks, confirmed scats and hairs, and back track coordinates) from our four winters of study,

> representing a minimum of five wolverines (from DNA samples). The mean elevation of these points was 5,956 feet, or 745m below timberline, and the minimum elevation was 4,960 feet, or 1,058m below timberline.
>
> A more recent analysis by Copeland mapped snow persistence over a seven-year period as an indicator of wolverine habitat. This analysis showed that most of the Ogden Mountain to Nevada Creek Region did not have persistent snow during those seven years, and presumably would not be considered good wolverine habitat.
>
> Because our wolverine use data contradict these attempts to define wolverine habitat based upon elevation and/or persistent snow, our project represents an interesting case study of wolverine behavior, and our results bring up other interesting questions.
>
> . . .
>
> Regardless of these questions, our data demonstrate that the Ogden Mountain to Nevada Creek Region represents valuable and heavily used wolverine habitat that would not even be considered as wolverine habitat in other analyses.

Gehman et al (April 2014). Snow-Tracking Surveys on the Helena National Forest.

The fact that wolverines in this area are heavily using habitat that "would not even be considered as wolverine habitat" under the Copeland model is deeply troubling because the 2013 Proposed Rule and programmatic biological assessment rely so heavily on this snowpack and elevation model. To apply the precautionary principle and best available science as required by the ESA, the agencies must re-examine their heavy reliance on elevation and snow pack when modeling wolverine habitat.

Finally, the same on-the-ground wolverine tracking efforts have also documented "[d]eclining detections of carnivores during the past several winters [that] coincided with large-scale logging along Telegraph Creek and the Continental Divide south of MacDonald Pass, and increased snowmobile activity in the region." It is not plausible for the agencies to continue to argue that land management activities pose no threat to wolverine.

For these reasons, the agencies must reinitiate programmatic ESA consultation on wolverine because there is new information that reveals effects on wolverine that have not yet been considered. Alternatively, or in addition, the programmatic ESA consultation violates the ESA for failure to apply the best available science. Alternatively or in addition, the agencies must address this new information/best available science during Project-level consultations.

If the violations of law described above are not cured within 60 days, the Alliance intends to file suit for declaratory and injunctive relief, as well as attorney and expert witness fees and costs.

Sincerely,
/s/ Rebecca K.Smith
Rebecca K. Smith, Counsel for Notifier

cc: U.S. Attorney General
U.S. Department of Justice
950 Pennsylvania Avenue, NW
Washington, DC 20530-0001

SDA

ited States
partment of
riculture

rest
rvice

rch 2005

Final Environmental Impact Statement

Snow Talon Fire Salvage

Lincoln Ranger District, Helena National Forest
Lewis and Clark County, Montana

Vol. 1 of 2—Chpts. 1–5 and Index

Summary of Determinations

The revised USFS Region 1 sensitive species list (USDA 2004i) includes nine terrestrial species identified as "sensitive" that are known or suspected to occur on the Helena NF. These species were previously presented in Table 19 as excluded species in this analysis according to the rationale also presented in that table. Narratives of basic biology and effects for these species are presented in the *Biological Evaluation for Terrestrial Wildlife Species-Snow Talon Fire Salvage Project* and are available in the Snow Talon fire salvage EIS project record. Determinations and effects summaries of the two sensitive species with habitat present in the project area (wolverine and boreal toad) are shown in Table 28. The black-backed woodpecker, northern goshawk, and Colombian sharp-tailed grouse were previously recognized (during the time period covered by the Snow Talon DEIS) as USFS sensitive species for Region 1 but are not included on the most recent, revised Region 1 sensitive species list (USDA 2004i).

Table 28. Summary of determinations analyzed sensitive species on the Helena NF.

Species	Determination and Summary of Conclusion of Effects
Wolverine (Sensitive)	**May Impact Individuals or Habitat, but Will Not Likely Result in a Trend Toward Federal Listing or Reduced Viability for the Population or Species;** *Suitable habitat present*. No acres of suitable habitat being moved to an unsuitable condition and no disturbance-related effects occurring. Further analysis of direct, indirect, irreversible, irretrievable, and cumulative effects are required.
Boreal Toad (Sensitive)	**May Impact Individuals or Habitat, but Will Not Likely Result in a Trend Toward Federal Listing or Reduced Viability for the Population or Species;** *Suitable habitat present*. No acres of suitable habitat being moved to an unsuitable condition and no disturbance-related effects occurring. Further analysis of direct, indirect, irreversible, irretrievable, and cumulative effects are required.

Wolverine (*Gulo gulo*)

The wolverine has been characterized as one of North America's rarest mammals and least known large carnivores (Ruggiero et al. 1994). Wolverines range widely from subalpine talus slopes to big game winter ranges, occupying higher ranges in the summer and riparian habitat in the spring. Ruggiero and others (1994) found that wolverines used higher elevations in the snow-free season to avoid high temperatures and human activity.

Wolverine habitat is best defined in terms of adequate year-round food supplies in large sparsely inhabited areas, rather than in terms of particular types of topography or plant associations. No particular habitat components or habitat management techniques can presently be singled out for wolverine; success of wolverine may relate to the availability of large areas of remote, rugged uplands that are difficult to access by humans (Hatler 1989). Preferred habitat appears to be large, isolated tracts of land supporting a diverse prey base. Wolverines occur in low densities in all places they have been studied (Ruggiero et al. 1994). This is generally attributed to naturally low reproductive rates and delayed sexual maturity of the species. Food availability seems to be the primary factor determining movement and specific habitat use.

Wolverines are generally solitary animals that exhibit some fidelity to particular areas for months or years. However, the species is thought to have a flexible behavioral system when affected by changing environmental conditions (e.g., food supply), which supersedes boundary considerations (Hatler 1989). The wolverine is generally described as primarily a scavenger during the winter and an opportunistic omnivore during the summer. The eggs and young of ground nesting birds, burrowing rodents, snowshoe hares, and berries are favorite summer foods. During the winter, wolverines rely on carrion from kills made by other predators or from natural winter mortality. The availability of winter carrion can directly influence winter use and denning suitability of an area.

Wolverines rely on winter dens primarily for the purpose of giving birth and rearing young. Various studies have found that the use of reproductive dens begins from early February to late March and in some cases females may use multiple dens before kit weaning. In Idaho, Copeland (1996) recognized natal dens for giving birth, subsequent pre-weaning maternal dens, and post-weaning dens classified as rendezvous sites. Rendezvous sites were oftentimes defined by a localized area rather than a specific den and appeared to provide security for kits in the female's absence.

Wolverine denning habitat parameters were produced for the Lincoln RD based on Copeland's (1996) study of wolverine denning habitat; Heinemeyer, Aber, and Doak's (2001) denning habitat model and survey; literature reviews; discussions with wildlife biologists; and on-the-ground knowledge of the Lincoln RD's landscape. Wolverine denning habitat was analyzed for all USFS lands on the Lincoln RD, north of Highway 200. Both potential and high potential wolverine denning habitat was identified and mapped.

The parameters chosen to map the elevational band of habitat most commonly used by denning female wolverines are displayed in Table 29. These parameters characterize high-elevation cirque basins at or above timberline, and subalpine meadows and/or subalpine forest types within 500 feet below these basins on slopes where snow would remain throughout the denning season.

Table 29. Wolverine habitat parameters analyzed for the Snow Talon fire salvage.

Habitat Type	Elevation (feet)	Slope (%)	Cover[a]	Aspect (Cardinal)
Potential	>6,200	>35 and <100	Rock cover types, open meadow cover types, and SAF, WBP, ES, SAL cover types within 500 feet of rock and open meadow cover types	N/A
High Potential	>6,200	>35 and <100	Rock cover types, open meadow cover types, and SAF, WBP, ES, SAL cover types within 500 feet of rock and open meadow cover types	N, NE, NW and aspects

a. SAF = subalpine fir, WBP = whitebark pine, ES = Engelmann spruce, SAL = subalpine larch.

Affected Environment—Wolverine

A total of 177,673 acres of USFS lands were analyzed for wolverine denning habitat. Within the fire perimeter, 1,534 acres met the parameters for potential denning habitat and 642 acres met the parameters for high potential denning habitat. Approximately 20 acres of potential denning habitat fall within proposed harvest units. No high potential denning habitat was identified within proposed harvest units. The 20 acres of potential denning habitat fall within one helicopter unit (Unit 4) common to Alternatives 2 and 4. There is no overlap of proposed harvest units and denning habitat in Alternative 3.

Wolverine sightings have occurred in the upper portions of the project area before the Snow Talon wildfire. Areas around the head end of drainages, in high, secluded basins within the project area such as Copper Creek, Red Creek and Cotter Creek were known to be good wolverine habitat. Suitable wolverine

Wolverine den on high-elevation slopes, steep enough and shaded enough to hold snow throughout the denning period. Wolverine seem to key in on site location; not specific habitats (Copeland 1996). Habitat type and forest structure is not thought to influence wolverine denning preference. The removal of dead trees through salvage harvesting as specified in Appendix D would not directly alter denning habitat suitability. However, salvage harvest activities could result in disturbance or displacement of wolverine from suitable denning habitat depending on the timing and location of activities. As only 20 acres of overlap of potential denning habitat and harvest units were identified, the potential for the loss or disturbance of structural components, such as down trees that could contribute to suitable den sites would be minor. The potential for disturbance or displacement of individuals from den sites from salvage harvest activities is greater, however, because of the proximity of additional acres of suitable denning habitat near harvest units. The magnitude of potential effects would be similar for Alternatives 2 and 4 but considerably lower for Alternative 3, which does not include salvage harvest units in the upper reaches of the drainage where denning habitat occurs.

Some level of project implementation would occur during summer and winter seasons under each of the action alternatives. Under Alternatives 2 and 3, all tractor and skyline harvest would occur during the winter and helicopter harvest in Alternatives 2 and 4 would most likely occur during the summer, but could extend into winter. The removal of dead trees should not directly affect wolverine habitat, but disturbance-related effects associated with harvest activities could indirectly affect individuals. Helicopter logging during the denning period has the greatest potential to disrupt reproductive success. Reproductive denning occurs from February through May, so the potential for helicopter logging to affect denning activities would be limited to the month of February as all logging operations would cease from March 1 through spring breakup, typically late May or June. Overall, the potential to effect suitable denning habitat or denning success of individuals is low. Extensive snowmobile activity that occurs throughout the drainage makes the likelihood of wolverines using the area for reproductive denning very low.

Winter ground-based logging activities would have no direct effect upon denning habitat as no tractor or skyline units overlap with denning habitat. Both winter ground-based logging and summer helicopter operations could potentially disrupt foraging activities of individual wolverines.

Ground-based salvage logging activities would have minimal effects upon individual wolverine through disturbance-related effects because of the salvaging occurring in the lower portions of the Copper Creek drainage away from high-quality, high-elevation, habitat located at the head ends of the basins. If wolverines moved through the lower reaches of the drainage during the ground-based salvaging activities, individual wolverines could be displaced to other areas from the increased human activity. The overall remoteness of the drainage, numerous displacement areas, roadless areas, the Scapegoat Wilderness, and areas with no activity occurring should provide adequate hiding and traveling areas for wolverines moving through the area. These abundant remote areas would remain available throughout project implementation and no activities would affect wolverine during their critical denning season. Disturbance and displacement-related effects would be extremely rare events confined to incidents with individual traveling wolverines and would, therefore, be insignificant.

The construction of temporary road segments, placement and removal of the two temporary bridges, jammer trail reclamation, and tree planting would have insignificant effects upon wolverine or their habitat.

The retention of live trees, snags, and down logs across the landscape would adhere to the Conifer Tree Retention Guide (Appendix D) for all action alternatives and would reduce the impacts to wolverine prey species. Snags would be retained in clumps and individually to provide suitable foraging and nesting habitat for avian species and to provide hiding cover, habitat connectivity, and travel pathways for terrestrial species. Down logs would be retained throughout units to provide cover, foraging, and potential denning habitat.

Direct and Indirect Effects of Alternative 2

Timber salvage and subsequent effects to wolverine would occur on approximately 2,433 acres or 7% of the total USFS lands burned by the Snow Talon fire. The removal of dead trees across these acres would have some short-term effects upon wolverine prey distribution and abundance but may improve long-term forage production and availability for ungulate prey species. Approximately 20 acres of potential wolverine denning habitat would be helicopter logged in Unit 4 in the upper portion of the drainage. The likelihood of individuals denning within these 20 acres is low due to the high level of snowmobile activity during the winter. Additionally, the potential period of overlap between helicopter logging operations and the denning period is short due to the logging restriction from March 1 through spring breakup. Helicopter overflights could, however, disturb or displace individuals from adjacent denning and foraging habitat during winter operations. The winter salvage harvest of tractor and skyline units has a very low potential of disturbing wolverine denning activities due to the short period of overlap (the month of February) between logging operations and the wolverine denning period. No wolverine denning habitat occurs within tractor or skyline units and the distance of these units from suitable denning habitat minimizes the potential of disturbance-related effects to individuals during the denning period. Ground-based logging operations and summer helicopter operations do have some potential to disturb or displace foraging individuals.

Direct and Indirect Effects of Alternative 3

Timber salvage and subsequent effects to wolverine would occur on approximately 1,103 acres or 3% of the total USFS lands burned by the Snow Talon fire. Helicopter logging would not occur under this alternative. No salvage harvest would occur within suitable wolverine denning habitat and the distance between ground-based logging units and suitable denning habitat minimizes the potential for indirect disturbance to individuals from logging operations. The proposed tractor logging of 820 acres and skyline logging of 283 acres during winter only is consistent with Alternative 2 and the potential effects for these activities would be similar under this alternative. The magnitude of effects under this alternative, however, would be less than for Alternatives 2 and 4 because fewer acres would be harvested, no wolverine denning habitat would be impacted, and the duration and level of harvest activities would be less.

Direct and Indirect Effects of Alternative 4

Timber salvage and the subsequent effects to wolverine would occur on approximately 3,692 acres or 11% of the total USFS lands burned by the Snow Talon wildfire. In addition to the increased acres for helicopter and winter tractor logging, this alternative includes summer tractor logging on 523 acres. The effects of helicopter and winter tractor logging under this alternative would be similar to those described for Alternative 2. However, the additional acreages would increase the magnitude of those effects and the extended project duration would increase the time of disturbance. The addition of summer tractor logging would increase the potential for direct effects to wolverine prey species due to the overlap with the reproductive period for most species. Helicopter logging would occur on 20 acres of potential wolverine denning habitat as in Alternative 2.

The harvest of approximately 930 acres proposed within IRAs would result in the largest contiguous block of habitat with low snag densities and limited screening cover. These acres occur on a gentle, descending ridgeline between the Copper Creek and Landers Fork drainages and provide a travel corridor for elk and deer to move between drainages and to migrate between seasonal habitats from the valley floor to the wilderness. The private lands bordering these acres to the east have been extensively logged in the past and have high road densities. The area does not provide the quality remote habitat or security for wolverine, as do other roadless areas and untreated areas within the project area. Areas such as the head end of the Red Creek and Copper Creek basins contain live, forested stringers, head ends of basins, and habitat is still present within the uppermost reaches of these basins, where the fire burned in a mosaic pattern and at lower intensities.

The most far-reaching effect of past management activities has been the development of road systems, recreational trails, and sites that improved access and promoted human use in remote areas. Winter snowmobile activity and other motorized recreational uses have reduced the remoteness of the natural landscape. The Snow Talon fire temporarily reduced foraging opportunities for wolverine throughout most of the project area until vegetation recovers and small mammal, bird, and ungulate populations become re-established. Wolverine habitat continues to exist within the watershed although changes in use of this habitat by wolverines may occur in response to the differences in distribution and abundance of food resources. As studies of wolverine are few and inconclusive, it is difficult to determine the exact effects past management actions have had on wolverine within the watershed. Generally, it is likely that unroaded remote areas provide higher quality habitat. Activities or conditions that enhance the ungulate prey base contribute more to the quality of wolverine habitat than those that reduce the ungulate prey base.

Environmental Consequences—Wolverine

No key issues or analysis issues specific to the wolverine were identified in Chapter 1; however, sensitive species as a whole were identified as an analysis issue. The following effects indicators were used to focus the wolverine analysis and disclose relevant environmental effects:

- An assessment of effects on potential prey species (big game) of wolverine
- Levels of potential disturbance during the denning period.

Direct and Indirect Effects of Alternative 1

Under this alternative, short-term effects on potential carrion sources for wolverine would be minimal. The short-term loss of ungulate forage (1–3 years) and thermal cover may result in some additional over-winter mortality of ungulates, which would provide carrion sources for wolverine. The extent of over-winter mortality is variable depending upon weather patterns that influence forage production (growing season precipitation) and winter caloric requirements of ungulates, particularly under extreme winter temperatures. Due to the lack of winter range within the project area, however, increases in available carrion from over-winter mortality would be expected to be minimal. Indirect effects potentially include a longer vegetative recovery time in portions of the burn where natural conifer regeneration is poor and subsequently extend the time of recovery for the ungulate prey base.

Additional losses of live conifer habitat as a result of fire-related stress and possible beetle outbreaks within the remaining live stands would have negligible effects upon wolverine. With no jammer trail reclamation under this alternative, potential illegal motorized use could result in some short-term disturbance or displacement of individual wolverines. Wolverine denning habitat would not be affected under this alternative.

Direct and Indirect Effects Common to Action Alternatives

Actions associated with the project would result in zero (0) acres of habitat moved to an unsuitable condition. The removal of dead trees would have minimal effect upon wolverine use and movement. Some short-term disturbance or displacement may result from harvest operations; however, blocks of land left unmanaged, adequate displacement areas, and long-term improvements in ungulate foraging conditions would minimize potential effects to wolverine. As vegetation recovers and other prey species become re-established, wolverine foraging opportunities would improve.

are connected to even larger remote areas outside of the project area. Salvage harvest of these burned acres would have minimal direct effects upon wolverine because of the low habitat suitability; however, harvesting may indirectly affect wolverine by changing ungulate use of the area in the short term.

The addition of 275 acres of potential beetle salvage units under this alternative would increase implementation duration from 2 years (salvage of burned trees) to 4–5 years (salvage of burned and beetle-killed trees). Direct habitat modification effects would be similar to burned tree salvage. Human disturbance-related effects would last longer with project implementation because more acres are being treated.

The types of effects under Alternative 4 would be similar to those under Alternatives 2 and 3, but the magnitude would be greater due to the additional acres treated, summer tractor logging would have greater potential to displace or affect reproductive success of wolverine prey species, and the potential for disturbance or displacement of wolverine would be greater due to the longer implementation period.

Cumulative Effects Common to All Alternatives

Cumulative effects to wolverine are varied. Past vegetative manipulations probably had minor direct effects on this habitat generalist. Past forest management harvest activities benefited wolverine by providing early seral conditions preferred by ungulate species, an important food source for wolverine. This successional plant stage provided the needed forage in a landscape where fires were being actively suppressed. Harvesting created a diversity of conditions: berry patches, ground and tree squirrel habitat, and other foraging sources for wolverine. Human developments such as the Copper Creek Campground, hiking trails, and road development within the drainage probably had more effects by increasing human access into once remote areas. Roads that accessed high-elevation basins probably reduced habitat quality the most.

Mushroom harvesting is an activity with potential to displace or influence wolverine within the burned portions of the drainage. This activity occurred in the spring/summer of 2004 and brought hundreds of people to the drainage primarily in lower elevation areas. Mushroom harvesting is expected to occur again during summer 2005 but at substantially lower human-use levels resulting from reduced mushroom production. Copeland (1996) believes that over-the-snow vehicles and increased interest in winter recreation likely displaced wolverines from potential denning habitat in central Idaho. Snowmobiling occurs throughout the Copper Creek watershed and this recreational activity may be having displacement effects on wolverines.

Alternatives 2 and 3 would have similar effects on prey availability for wolverine and Alternative 4 has a greater potential to disrupt ungulate use of the area for the short term. Each action alternative would decommission old jammer trails. The environmental baseline during winter and non-winter appears to be suitable to sustain wolverine use. Recreational activities may have had displacement effects on wolverine with their introduction to the area, but these activities have been present for decades and seem to be remaining constant. Recreation activities did reduce the habitat quality of certain remote areas, but many large remote areas still exist. Wolverines have been documented in the area for many decades and should remain as long as current conditions do not drastically change. No alternative would have long-term adverse cumulative effects on wolverine or habitat suitability.

Conclusion/Determination

It is the determination of this analysis that each of the action alternatives "May Impact Individuals or Habitat, but Will Not Likely Result in a Trend toward Federal Listing or Reduced Viability for the Population or Species," on the wolverine or its habitat.

Helicopter

cause individual animals to expend energy to move away from the disturbance. Moose disturbed by snowmachines and skiers could further be disturbed by helicopter overflights. Such a disturbance would be relatively minor and short term.

Comparison of Alternatives
Under Alternative 1, No Action, CPG's permit would not be issued and no helicopter skiing would occur on the Kenai Peninsula geographic area unless another permit were applied for and granted. As a consequence, there would be no impacts to the moose. Under all action alternatives, heli-skiing operation may affect individual moose. However, helicopters must maintain a 1,500 feet AGL at all times except shuttling passengers from the bottom to the top of a run, during landing and takeoffs, and if safety would be compromised. Helicopters may not hover, circle, or harass moose in any way. Therefore, it is unlikely that any action alternative would have a substantial effect on the moose. Alternatives 4 and 9 would have less impact on the moose, as heli-skiing would not be permitted in the Mt. Ascension and Snow River units, thereby eliminating over-flights of moose winter range in these areas.

Species of Special Interest
The Species of Special Interest that could experience *low to moderate* impacts from heli-skiing is the wolverine. The bald eagle, Canada lynx, and gray wolf could experience *low to negligible* impacts. There would be *negligible* effects on the river otter, northern goshawk, marbled murrelet, and Townsend's Warbler. They will not be discussed further in this document.

Wolverine--
Direct Effects
Given the lack of studies on wolverine, it is not surprising that none of the published information deals directly with the issue of helicopter disturbance on this species. However, there is evidence that the species may tolerate human intrusion poorly, particularly when the disturbance is near reproductive denning sites.

Denning females could be displaced by helicopter skiing activities occurring in denning areas and could abandon their den sites. Myrberget (1988) mentions four instances of den abandonment due to human disturbance and suggests that secondary dens may be less suitable. Direct contact occurred with two denning females in Idaho in late April and May and resulted in den abandonment in both cases (Copeland 1996). Abandonment of den sites would adversely impact both the female wolverine and her kits. The natal denning period is a critical time for females because they must maintain energy levels to properly nourish their kits during a time when food is scarce. Disturbance during this time, when the females are lactating, could lead to increased energy expenditure and reduced fitness. Kits are at risk to various sources of mortality if they have to abandon their den site. Kits are more vulnerable to predation while being moved to a new den site, or when kept at insecure sites (Magoun and Copeland 1998). They could also experience loss of fitness due to nutritional stress induced by the mother's search for and move to a new den site. Magoun and Copeland (1998) reported instances where although females did not abandon natal dens after disturbances from humans, associated maternal dens, which are speculated to be less "secure" than natal dens, were abandoned within hours of being disturbed by humans

Wolverines may be distributed across all of the units proposed for heli-skiing (Golden et al. 1993). Wolverine tracks were located in Seattle Creek, Bench Peak, Moose Creek, Ptarmigan, Snow River and Mt. Ascension. Placer-Skookum, Grandview, and units north of the Turnagain Arm were not surveyed. Heli-skiing in remote areas has the potential to displace wolverines, or disrupt foraging or travel patterns. Wolverines may abandon dens after human disturbance (Heinemeyer et al 2001). Den abandonment can lead to reduced reproduction or lower kit survival (Magoun and Copeland 1998).

Indirect Effects
No indirect effects are expected.

Cumulative Effects
Heli-skiing in combination with other motorized and non-motorized winter recreation activities in remote areas would result in a cumulative disturbance to wolverine. Although the denning period appears to be the most critical time for wolverine breeding success, it is possible that individuals of either gender could be displaced due to the presence of any type of backcountry recreationists including heli-skiers. Unless an area was to receive repeated and high frequency use, it is unlikely that such a displacement would be permanent or result in long-distance movements. Wolverines maintain extensive territories and disturbance in one area of their territory would likely lead only to an individual refocusing its activities elsewhere within its territory. Wolverine surveys beginning in the winter of 2003-2004 will aid in identifying distribution, density, and denning habitat.

Comparison of Alternatives
Under Alternative 1, No Action, CPG's permit would not be issued and no helicopter skiing would occur on the Kenai Peninsula geographic area, unless another permit were applied for and granted. As a consequence, there would be no impacts to wolverine. Under all action alternatives, heli-skiing operation may affect individual wolverine. However, helicopters must maintain a 1,500 feet AGL at all times except shuttling passengers from the bottom to the top of a run, during landing and takeoffs, and if safety would be compromised. If a wolverine den is located (either by CPG or during wildlife observation flights), then CPG would maintain a 1/2 mile horizontal or 1,500 AGL separation during their operations. Helicopters may not hover, circle, or harass wolverine in any way. Therefore, it is unlikely that any action alternative would have a substantial effect on wolverine or impact wolverine populations or viability.

Bald Eagle--
Direct Effects
Helicopter flights have the potential to disturb nesting and foraging eagles. Reactions to helicopters are reportedly mixed and may be related to the amount of helicopter hovering time spent above a nest, height above the nest, or the frequency of flights in a nest's vicinity (Hancock 1966, White and Sherrod 1973, Call 1979). Bald eagles typically utilize lower elevations along open water in winter, habitat conditions that do not occur at the altitudes and locations where heli-skiing activities take place. Some over-flights of individuals utilizing habitat near helicopter staging areas could occur. To minimize any possible effect on the bald eagle, two mitigation measures have been formulated. (1) No

FS-MT-030216-F

United States Department of Agriculture

Forest Service

Bitterroot National Forest

May 2003

CANYON LAKE DAM AND WYANT LAKE DAM PROJECT

Final Environmental Impact Statement

Canyon Lake Dam

areas around Canyon and Wyant Lakes. This increased use could result in minor additional disturbance effects to wolverine in the future.

Cumulative Effects

The analysis area for cumulative effects to wolverine is the Bitterroot Mountains. The existing condition reflects the sum of past activities. Major past activities in this area are described in the elk section. The direct and indirect effects of all of the alternatives are described above. None would appreciably add to nor subtract from the existing cumulative effects. Reasonably foreseeable future projects in the Bitterroot Mountains are listed in the Burned Area Recovery EIS (USDA Forest Service, 2001).

Effects Call

The effects call for wolverine in the Biological Evaluation is No Impact if Alternative A is selected, and May Impact Individuals or Habitat, but will not likely contribute to a trend towards federal listing or cause a loss of viability to the population or species if either Alternative B or C is selected. None of the alternatives would affect the viability of wolverine at any scale.

Coeur d'Alene salamander (*Plethodon idahoensis*)

This small terrestrial salamander is generally found below 5,000 feet in elevation in seeps, spray zones and splash zones of waterfalls along streams and creeks. They occur in wet, humid and cool microhabitats containing fractured bedrock or large boulders that provide shelter and retain moisture. Dense tree canopy over cascading creek sites is an important habitat component because it moderates surface and water temperatures. These salamanders remain subsurface during the day. They hibernate underground from November to April. Removal of overstory vegetation, increases in water temperature, changes in water table and flow, and physical disturbance of talus or rock habitat can affect Coeur d'Alene salamander populations.

Recent surveys have documented Coeur d'Alene salamanders at three sites in the Bitterroot Range, including Sweathouse, Rock and Chaffin Creeks. The distance between these locations indicates that this species may be widespread in suitable habitat in the Bitterroots, although earlier surveys in other drainages did not detect any individuals (Genter, et al. 1998). There is some suitable habitat in Canyon Creek, and it is possible that this species occurs in the drainage.

Direct and Indirect Effects

Alternative 1

The No Action Alternative would have no direct or indirect effects on Coeur d'Alene salamanders or their habitat.

meadows. There seems to be little use in stands of dense young timber or in actual openings such as clearcuts or wet meadows (Reel, et al. 1989; Butts, 1992).

Wolverine home ranges are very large, averaging approximately 150 square miles in Montana. Wolverine feed primarily on rodents and carrion, although they are opportunists and will also consume berries, insects, fish, birds and eggs when available. Ungulate carrion seems to be particularly important in the winter, and wolverine movement to lower elevations during winter may be to take advantage of ungulate mortalities on winter ranges (Reel, et al. 1939; Butts, 1992). Ungulate carcasses attributable to wounding losses during hunting season also appear to be important food sources for wolverines during the winter at all elevations.

Recent sightings of wolverines in the Bitterroot Range include animals in Lost Horse, Camas and Sweathouse Creeks. Suitable wolverine denning habitat exists in the higher basins within the Canyon Creek drainage. Wolverine could also utilize the lower portions of the drainage during the winter. It is likely that some wolverine use occurs in the drainage, although the entire analysis area would constitute only a small portion of the home range of one wolverine.

Direct and Indirect Effects

Alternative 1

The No Action Alternative would have no direct or indirect effects on wolverine or their habitat.

Alternative 2

None of the options within this alternative would affect existing wolverine habitat or den sites. There is a small chance that construction activities and/or helicopter flights to the dams could potentially disturb wolverine to a minor degree if any happened to be in the area. Helicopter flights would not disturb wolverine dens since none would occur during the winter denning season. Workers or administrative personnel walking up the trail to the dams would not disturb wolverine any more than a hiking party. Any of these disturbances would be minor and temporary, and none would result in any lasting adverse effects to wolverine.

Alternative 3

None of the options within this alternative would affect existing wolverine habitat or known den sites.

There is a small chance that construction activities and/or helicopter flights to the dams could potentially disturb wolverine to a minor degree if any happened to be in the area. The trail improvement and construction required to access the dams with pack stock, and to restore the trails to their original condition after the project has the potential to cause some disturbance to wolverine in the area. Workers or administrative personnel walking up the trail to the dams would not disturb wolverine any more than a hiking party. It is unlikely that this level of disturbance would have any lasting adverse effects to wolverine. The proposed trail improvement and construction would likely lead to increased recreational use of the trail and the

Alternative 3

None of the options within this alternative would affect existing fisher habitat.

Construction activities proposed at the dams under this alternative would not affect fisher since the dams are not fisher habitat. Helicopter flights to the dams would have little effect on fisher, which are largely nocturnal. The trail improvement and construction required to access the dams with pack stock, and to restore the trails to their original condition after the project has the potential to cause some disturbance to fisher in the area. Workers or administrative personnel walking up the trail to the dams would not disturb fisher any more than a hiking party. It is unlikely that this level of disturbance would have any lasting adverse effects to fisher. The proposed trail improvement and construction would likely lead to increased recreational use of the trail and the areas around Canyon and Wyant Lakes. This increased use could result in minor additional disturbance effects to fisher in the future.

Cumulative Effects

The analysis area for cumulative effects to fisher is the Canyon Creek drainage. The existing condition reflects the sum of past activities. Major past activities in this area are described in the elk section.

The direct and indirect effects of all of the alternatives are described above. None would appreciably add to nor subtract from the existing cumulative effects. Reasonably foreseeable future projects in the Canyon Creek drainage include spraying herbicides along the roads and trails to control noxious weeds, and surfacing of parts of the Blodgett and Canyon Creek roads.

Effects Call

The effects call for fisher in the Biological Evaluation is No Impact if Alternative A is selected, and May Impact Individuals or Habitat, but will not likely contribute to a trend towards federal listing or cause a loss of viability to the population or species if either Alternative B or C is selected. None of the alternatives would affect the viability of fisher at any scale.

Wolverine (*Gulo gulo*)

The US Fish and Wildlife Service (USFWS) recently received a petition to list the wolverine as Threatened or Endangered throughout its range. The USFWS review process will take several years. In the interim, the wolverine has no legal status under the Endangered Species Act. However, the Regional Forester's Sensitive Species List includes the wolverine as a Sensitive species on the Bitterroot National Forest and throughout Region One.

Wolverine are solitary animals that range widely over a considerable variety of habitats. Habitat requirements tend to include large, isolated roadless areas that support a diverse prey base. Within such areas, wolverine use appears to be concentrated in areas of medium to scattered mature timber and in ecotonal areas around natural openings such as cliffs, slides, basins and

Snow-Tracking Surveys on the Helena National Forest

December 2012 – March 2013

Prepared by Steve Gehman, Kalon Baughan, and Betsy Robinson

April 2014

WILD THINGS UNLIMITED

Displace = 9

Table of Contents

- use els down to 4900-5900 winter 6700
- like heavy cover
- not persist snow all ? yrs.

5965 = mean winter el.
4960 = min

was with NC-7 (Table 6). Unfortunately, hair samples collected on gun brushes mounted at the camera site yielded DNA evidence from only one of the three wolverines (HFW13-F9, or NC-8).

A fourth wolverine, HFW10-M3 (SC-2) also visited the primary Nevada Creek camera station. This wolverine, known mainly as the dominant male in the Dalton Mountain to Ogden Mountain area, visited the Nevada Creek camera station three times. Each time his visit occurred one day after the same station was visited by one or more of the three Nevada Creek wolverines: SC-2 was first photographed at this site on March 7, and NC-8 was photographed there on March 6; SC-2 visited next on April 22, and NC-7 and NC-9 were there on April 21; and SC-2 was photographed a third time on May 20, the day after NC-7 visited on May 19 (Table 7). These data suggest that wolverine SC-2 (HFW10-M3) was following the trails of the other three wolverines, and that those trails led him to the Nevada Creek camera station.

Photographs of HFW13-F9 (NC-8) indicated that she suffered from extensive hair loss during spring 2013. The first photo that showed hair loss was taken on March 2, 2013; a photo taken on March 13 showed increased hair loss, and a photo from April 10 showed advanced hair loss (Figure 5).

A second camera station was operated in Nevada Creek for 27 days, at a carcass that was discovered while back tracking a wolverine trail on January 5, 2012; no wolverines returned to this site, but the camera recorded visits by mountain lion, red fox, coyote, and two golden eagles (Table 5).

Summary and Conclusions

Helena Ranger District

Although we increased the level of survey effort in the MacDonald Pass/Helena Ranger District study area during winter 2012-2013 compared to the previous winter (nine days, 23 surveys, and 216 km covered in winter 2012-2013, compared to one day, four surveys, and 33 km covered in winter 2011-2012), we had no success documenting wolverine or lynx activity. Declining detections of carnivores during the past several winters coincided with large-scale logging along Telegraph Creek and the Continental Divide south of MacDonald Pass, and increased snowmobile activity in the region.

Lincoln Ranger District

Our fourth winter of conducting carnivore surveys on the Lincoln Ranger District was very productive, with snow-track transect surveys, backtracking sessions, and remotely-triggered cameras once again providing an abundance of information about lynx and wolverine activity.

Surveys in the Dalton Mountain – Ogden Mountain area revealed high levels of lynx and wolverine activity, in addition to presence of mountain lions, bobcats, martens, wolves, and coyotes.

With no addition of "new" lynx, the total number of lynx identified from scat and hair samples collected by WTU over the course of this study remained the same, at seven (HFW10-L-M3,HFW11-L-M4, HFW11-M5, HFW11-L-F6, HFW11-L-F7, HFW12-L-M8, and HFW12-F9). Two of these lynx were among the five lynx captured and marked by the Forest Service lynx research crew in the Dalton Mountain to Ogden Mountain area during 2012 and 2013 (HFW11-l-L-M5 is also known as M162 and HFW11-L-F6 is also known as F164). Adding the three remaining marked lynx (F170, M163, and M???) to the seven lynx mentioned above yields a minimum of 10 lynx (four males, six females) that used the Dalton Mountain to Ogden Mountain area during the four period of winter 2009-2010 through winter 2012-2013 (Table 8; Fig. 6).

With the genetic identification of two more wolverines, we now have genetic confirmation for seven wolverines that used the Ogden Mountain to Nevada Creek region in four winters of study (Table 7; Fig. 7). These individuals include three males and four females, as follows: HFW10-M3 (identified from samples collected in winters 2009-2010 and 2010-2011), HFW10-F4 (identified from one sample collected in winter 2009-2010), BDF10-M6 (first identified from a sample collected on the Beaverhead-Deerlodge National Forest in winter 2009-2010, and then identified from samples collected in the Dalton Mountain region in winters 2011-2012 and 2012-2013), two females, HFW12-F7 and HFW12-F8 (identified from samples collected in winter 2011-2012), HFW13-F9 (identified from 18 samples collected in winter 2012-2013, and 2013-Male1 (identified from one sample collected by the Forest Service crew in March 2013).

Three of these seven wolverines can be positively linked to photographs obtained at our camera stations operated in the Ogden Mountain to Nevada Creek region during the past three winters. From examining the timing and locations of photographs, backtracking sessions, and DNA sample collections, we believe that we have obtained photographs of HFW10-M3 (designated SC-2 in photos; winters 2010-2011, 2011-2012, and 2012-2013), HFW10-F4 (designated SC-1 in photos; winters 2010-2011, 2011-2012, and 2012-2013), and HFW13-F9 (designated NC-8 in photos; winters 2011-2012 and 2012-2013) (Table 7; Figs. 4 and 5).

Similarly, we believe it is highly likely that wolverine 2013-Male1 is NC-9, the brother of NC-8 (photographed in winters 2011-2012 and 2012-2013). We have obtained photos of NC-7 (winters 2011-2012 and 2012-2013), the mother of NC-8 and NC-9, but have not yet obtained genetic samples from this animal. For three additional wolverines that were photographed, we can only speculate that they may be among the genetically identified individuals; it is possible that SC-3 and/or MC-4 could be represented by HFW12-F7 and HFW12-F8, and possible that NC-5 could be the same animal as BDF10-M6 (Table 7).

If we add NC-7 to the seven genetically known wolverines, we arrive at a conservative minimum of eight wolverines (five females, three males; Table 7) that used the Ogden Mountain to Nevada Creek region during the four year study period. We know that two of these wolverines are adult males, two are adult females, and that both of those females produced kits during the study period.

Snow-tracking and camera station results indicated that wolverines were active in the LRD study area during December 2012 and in each month from January through May 2013. As in 2011 and 2012, a significant amount of the late spring and summer activity was centered in the vicinity of upper Moose Creek (Table 6; Fig. 3). Our documentation of continued periodic activity in this region indicates that this area has high value for wolverines.

In each of the past four winters, wolverine trails revealed an east-west wolverine travel pattern across the central portion, and higher elevations, of the Dalton Mountain – Ogden Mountain area (Fig. 7). Elevations of wolverine tracks and trails in the Dalton Mountain – Ogden Mountain area during those four winters ranged from 4,930' in Willow Creek to 6,730' on the saddle between Jefferson Creek and McClellan Gulch, east of Dalton Mountain. In Nevada Creek, documented wolverine activity occurred between 5,240' and 6,560' elevation, during three winters.

Further analysis of our wolverine location data suggests that the Ogden Mountain to Nevada Creek region represents atypical wolverine habitat. Wolverine expert Jeff Copeland once defined wolverine habitat as being from 200m above to 200m below timberline. We estimated timberline to be approximately 8,400 feet in the Ogden Mountain to Nevada Creek Region, based upon peaks along the nearby Continental Divide and in the Scapegoat Wilderness. We then analyzed 246 wolverine location data points (wolverine tracks, confirmed scats and hairs, and back track coordinates) from our four winters of study, representing a minimum of five wolverines (from DNA samples). The mean elevation of these points was 5,956 feet, or 745m below timberline, and the minimum elevation was 4,960 feet, or 1,058m below timberline.

A more recent analysis by Copeland mapped snow persistence over a seven-year period as an indicator of wolverine habitat. This analysis showed that most of the Ogden Mountain to Nevada Creek Region did not have persistent snow during those seven years, and presumably would not be considered good wolverine habitat.

Because our wolverine use data contradict these attempts to define wolverine habitat based upon elevation and/or persistent snow, our project represents an interesting case study of wolverine behavior, and our results bring up other interesting questions. For example, do our results suggest that wolverines are more adaptable than previously assumed? Are these results an indication that wolverines are expanding their range, and thereby shifting their distribution into lower elevation habitats? Do other similar wolverine "hot spots" exist within the Helena National Forest, the Southwest Crown of the Continent, the northern Rocky Mountains?

Regardless of these questions, our data demonstrate that the Ogden Mountain to Nevada Creek Region represents valuable and heavily used wolverine habitat that would not even be considered as wolverine habitat in other analyses. Perhaps this region possesses other characteristics that are attractive to wolverines and thereby compensate for elevation and/or snow cover. Such characteristics might include: 1) food availability – top level predators such as mountain lions, wolves, and human big game hunters provide feeding opportunities in the form of carrion, and we have documented numerous cases in which wolverines fed on elk and deer carcass remains; the region also supports high densities of small mammal prey species including snowshoe hare, red squirrel, and woodrat, and we have documented wolverine feeding sites that involved each of these species; 2) dense forest cover – numerous micro-habitats within the region include understory vegetation that is nearly impenetrable to humans, and such areas may represent patches of "secure" habitat to wolverines; and 3) unique geologic features – in numerous places there are large rock outcroppings, or boulder fields, that provide shelter, thermoregulation opportunities, and perhaps den sites for wolverines; we have followed wolverine tracks leading into such features many times, and have obtained photographs of several different wolverines repeatedly using one such boulder field in upper Moose Creek; one feature of these boulder fields is that they collect significant accumulations of snow in the winter -- we have observed that the lower levels of snow, within the spaces between rocks eventually turn into ice, and that this ice generally persists into summer (e.g. July 2011 and July 2012); the resulting cooler temperatures within boulder fields may be attractive to wolverines and may serve as a substitute for higher elevation habitat that is generally associated with wolverine summer activity.

The presence of at least ten lynx and at least eight wolverines in the portion of the Lincoln Ranger District south of Highway 200 during the past four winters, plus confirmation of reproduction by both lynx and wolverines in the region during the past three years, and the location of a unique wolverine rendezvous site indicate that this area represents extremely important habitat for these two rare carnivores.

NRC Research Press

ARTICLE

Wolverines (*Gulo gulo luscus*) on the Rocky Mountain slopes: natural heterogeneity and landscape alteration as predictors of distribution

J.T. Fisher, S. Bradbury, B. Anholt, L. Nolan, L. Roy, J.P. Volpe, and M. Wheatley

Abstract: A species' occurrence can be influenced by natural and anthropogenic factors; disentangling these is a precursor to understanding the mechanisms of distribution. Anthropogenic factors may be especially important at contracting range edges. We test this premise for wolverines (*Gulo gulo luscus* L., 1758) at the edge of their Rocky Mountain range in Alberta, Canada, a mosaic of natural heterogeneity and extensive landscape development. As wolverines have a suspected negative response to human activity, we hypothesized their occurrence on the Rockies' slopes is predicted by a combination of natural and anthropogenic features. We surveyed wolverines at 120 sites along a natural and anthropogenic gradient using hair trapping and noninvasive genetic tagging. We used abundance estimation, generalized linear, and hierarchical models to determine whether abundance and occurrence was best predicted by natural land cover, topography, footprint, or a combination. Wolverines were more abundant in rugged areas protected from anthropogenic development. Wolverines were less likely to occur at sites with oil and gas exploration, forest harvest, or burned areas, even after accounting for the effect of topography. The relative paucity of wolverines in human-impacted portions of this range edge suggests that effective conservation requires managing landscape development, and research on the proximal mechanisms behind this relationship.

Key words: range edge, wolverine, *Gulo gulo luscus*, occupancy models, abundance estimation, habitat fragmentation, landscape scale.

Résumé : La présence d'une espèce en un lieu donné peut être influencée par des facteurs naturels et humains; la compréhension des mécanismes de répartition commence entre autres par la clarification des rôles de ces facteurs. Les facteurs humains peuvent s'avérer particulièrement importants aux bordures d'aires de répartition en contraction. Nous vérifions cette hypothèse pour le carcajou (*Gulo gulo luscus* L., 1758) à la bordure de son aire de réparation dans les montagnes Rocheuses de l'Alberta (Canada), une mosaïque d'hétérogénéité naturelle et de secteurs aménagés. Comme il est soupçonné que le carcajou réagit négativement à l'activité humaine, nous avons postulé que sa présence sur les pentes des Rocheuses peut être prédite par une combinaison de caractéristiques naturelles et anthropiques. Nous avons étudié des carcajous en 120 sites le long d'un gradient naturel et anthropique en utilisant le prélèvement de poils à l'aide de pièges et le marquage génétique non invasif. Nous avons utilisé l'estimation de l'abondance et des modèles linéaires généralisés et hiérarchiques pour déterminer si le meilleur prédicteur de l'abondance et de la présence en un site était la couverture naturelle du sol, le relief, l'empreinte ou une combinaison de ces facteurs. Les carcajous étaient plus abondants dans les secteurs accidentés protégés de l'aménagement humain. Ils étaient moins susceptibles d'être présents dans des sites d'exploitation pétrolière et gazière et de coupe forestière ou dans des brûlis, et ce, même en tenant compte de l'effet du relief. La rareté relative des carcajous dans les portions de cette bordure d'aire de répartition touchées par des impacts d'origine humaine laisse croire que la conservation efficace nécessite la gestion de l'aménagement du paysage et de la recherche sur les mécanismes proximaux qui sous-tendent cette relation. [Traduit par la Rédaction]

Mots-clés : bordure d'aire de répartition, carcajou, *Gulo gulo luscus*, modèles d'occupation, estimation de l'abondance, fragmentation de l'habitat, échelle du paysage.

Introduction

Habitat loss, fragmentation, and alteration are a primary cause of many species' declines, and remain a pervasive anthropogenic phenomenon affecting ecological systems (Fahrig 1997, 2003). Determining the correlates of a species' spatial distribution across heterogeneous (and fragmented) landscapes is a key precursor to elucidating the ecological processes creating those patterns (e.g., Wiens et al. 1993). In particular, disentangling natural from anthropogenic correlates of distribution is a necessary requirement for effective conservation and management, and is often demanded when species conservation potentially conflicts with economically important landscape development. This task is further complicated because pattern and process can change markedly among landscapes as ecological and spatial contexts change, potentially preventing reliable inference from other landscapes (Fisher et al. 2005; Wheatley and Johnson 2009); this may be particularly true of circumboreal species distributed over highly varied landscapes, such as wolverines (*Gulo gulo* L., 1758).

Wolverines once inhabited boreal, tundra, and mountain habitats across North America and Eurasia (Pasitschniak-Arts and Larivière 1995) but their range has contracted, and populations declined,

Received 8 February 2013. Accepted 9 August 2013.

J.T. Fisher. Ecosystem Management Unit, Alberta Innovates – Technology Futures, Vegreville, AB T9C 1T4, Canada; School of Environmental Studies, University of Victoria, Victoria, BC V8W 3R4, Canada; Department of Biology, University of Victoria, Victoria, BC V8W 3N5, Canada.
S. Bradbury. Fish and Wildlife Division, Alberta Environment and Sustainable Resource Development, Edson, AB T7E 1T2, Canada.
B. Anholt. Department of Biology, University of Victoria, Victoria, BC V8W 3N5, Canada; Bamfield Marine Sciences Centre, Bamfield, BC V0R 1B0, Canada.
L. Nolan and L. Roy. Ecosystem Management Unit, Alberta Innovates – Technology Futures, Vegreville, AB T9C 1T4, Canada.
J.P. Volpe. School of Environmental Studies, University of Victoria, Victoria, BC V8W 3R4, Canada.
M. Wheatley. Provincial Parks Division, Government of Alberta, Hinton, AB T7V 2E6, Canada.
Corresponding author: J.T. Fisher (e-mail: Jason.Fisher@albertainnovates.ca).

 Published at www.nrcresearchpress.com/cjz on 12 August 2013.

since European colonization (Weaver et al. 1996; Laliberte and Ripple 2004; Aubry et al. 2007). On the eastern edge of their Rocky Mountain range in the province of Alberta, wolverines are listed as "Data deficient", reflecting a lack of sufficient data for legal designation (Petersen 1997; Alberta Fish and Wildlife Division 2008). Historical trapping records suggest wolverines were distributed across Alberta's Rocky Mountains, adjacent foothills, and boreal forests (Petersen 1997; Poole and Mowat 2001; Alberta Fish and Wildlife Division 2008), but their current distribution remains unknown and wolverines' range here receives continued human perturbation.

This landscape is a topographically diverse conifer forest mosaic with oil and gas exploration, forest harvesting, coal mining, roads, and motorized recreational access. All of these impacts remove forest cover or increase human access, but of these oil and gas exploration is the most spatially extensive. It produces very narrow seismic lines—ca. 3 m wide linear corridors cut into forests—crisscrossing the landscape in densities sometimes exceeding 25 km/km² (see also Schneider et al. 2003). Seismic lines remove forest cover and increase access for industrial activities (heavy-truck haulage, well pads, and pipelines) and motorized recreation (snowmobiles and off-road vehicles). Extensive spatial linear features and accompanying human activity are known to affect the movement, distribution, and ecological interactions of other mammals in this region (Whittington et al. 2005; Muhly et al. 2011; Fisher et al. 2012; McKenzie et al. 2012).

This anthropogenic mosaic grades into rugged, high-elevation mountain landscapes largely protected from anthropogenic footprint. The current edge of wolverines' distribution is believed to straddle this gradient (Laliberte and Ripple 2004), but the landscape features contributing to range demarcation (and by inference, range contraction) remain unknown. Natural features likely have an effect; we suspected that habitat alteration has a significant added effect that has gone unnoticed, or has been absorbed into a shifting baseline (sensu Pauly 1995) of wolverine rarity. Wolverines elsewhere avoid human-disturbed areas (Carroll et al. 2001; Rowland et al. 2003; May et al. 2006) and recreational and industrial activity (Krebs et al. 2007). Human activities such as trapping, poaching, and road mortality have accounted for 46% (North America; Krebs et al. 2004) to 52% (Scandinavia; Persson et al. 2009) of known-cause wolverine mortalities across their range. These studies focussed on individual mortality and site selection via telemetry; none have systematically examined wolverine abundance and occurrence across a gradient of landscape development and natural heterogeneity to examine the relative contribution of each in demarcating wolverine distribution. This was our objective.

We hypothesized that wolverines would be more abundant in areas without landscape development and that the probability of wolverine occurrence varies along a spatial gradient as a function of (i) land cover, (ii) topography, and (iii) the degree of landscape alteration, measured as seismic-line density and the percentage of area regenerating from forest fire and timber harvest. We predicted that wolverine abundance and occurrence would increase with land cover and topographic heterogeneity and decrease with habitat alteration.

Materials and methods

To test these hypotheses, we used noninvasive genetic tagging (NGT) through hair trapping (Waits 2004; Kendall and McKelvey 2008) to survey spatial patterns of wolverine occurrence (e.g., Flagstad et al. 2004; Mulders et al. 2007; Hedmark and Ellegren 2007; Fisher et al. 2011; Magoun et al. 2011). For robust inference, we related these parameters to landscape composition using three approaches: abundance estimation models (Amstrup et al. 2010), species distribution models (Franklin and Miller 2009), and occupancy models (MacKenzie et al. 2002, 2006), ranked in an information-theoretic framework, to determine those factors that best explained wolverine occurrence.

Study area

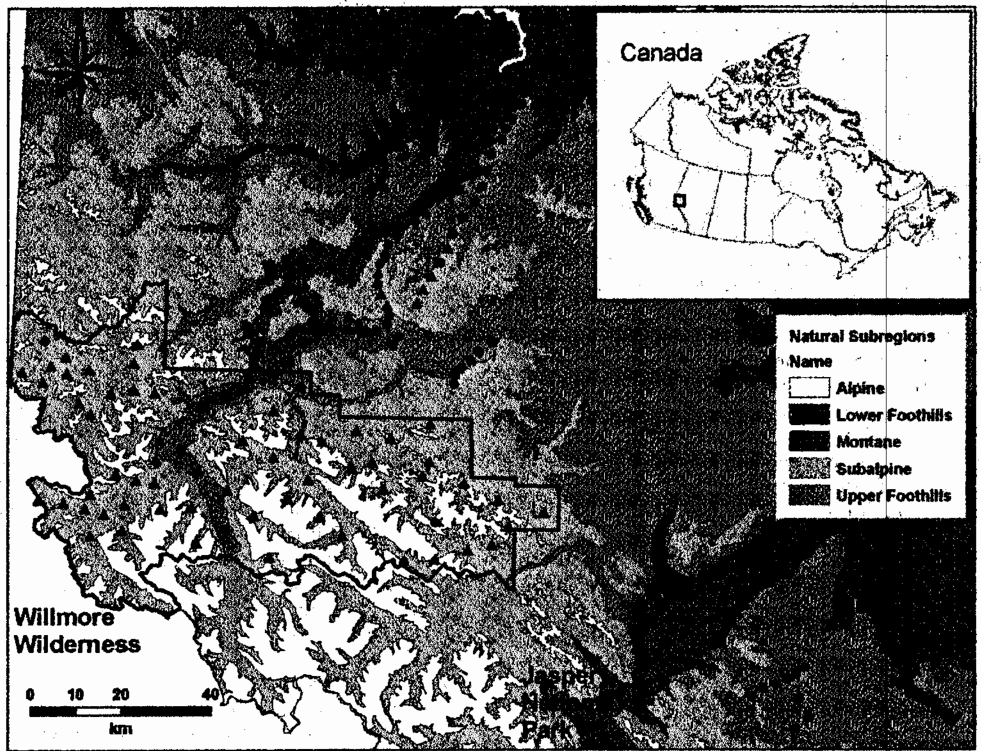
We sampled wolverine occurrence along an approximately east–west gradient (trending to northwest–southeast) spanning the Main Ranges, Front Ranges, and Upper Foothills of the Rocky Mountains in Alberta, Canada (Fig. 1). The area receives high precipitation and winter snow accumulation >2 m. The western end of the gradient is topographically rugged with peaks up to 3000 m, steep-sloped ridges, and wide valley bottoms. Slopes are forested by Engelmann spruce (*Picea engelmanni* Parry ex Engelm.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). The mountains grade eastward into subalpine, upper foothills, and montane natural subregions (Downing and Pettapiece 2006), with elevations ranging to 1700 m. Forests are commonly mixed mature lodgepole pine (*Pinus contorta* Douglas ex Loudon) with white spruce (*Picea glauca* (Moench) Voss) or balsam fir (*Abies balsamea* (L.) Mill.). The west is protected from development within the Willmore Wilderness Area, a 4600 km² conservation area exempt from forest harvesting, mining, petroleum exploration, roads, and motorized transport, though with recreation, off-road trails, and large burns. From the Willmore, the landscape grades into an increasingly intensive network of roads and seismic lines for petroleum exploration (Fig. 2); conifer forests have been harvested since approximately 1955. This is a mosaic landscape of different forest stand ages, habitat alteration, motorized access, and industrial and recreational human activity. Fur trapping occurs across both landscapes with about <5 animals taken each year (Petersen 1997; Poole and Mowat 2001).

Experimental design

Methods and design mirror Fisher et al. (2011, 2012). Wolverine occurrence was sampled with noninvasive genetic tagging (NGT) via hair sampling at 120 survey sites (Fig. 3). Hair traps consisted of a tree loosely wrapped with Gaucho® barbed wire (Bekaert, Brussels, Belgium). We baited this tree with a large (ca. 15 kg) skinned beaver carcass and O'Gorman's LDC extra scent lure (O'Gorman's Co., Montana, USA). Sampling sites were deployed in early December and sampled monthly through the end of March—a period when food is scarce and bait is most effective in attracting mammals. We sampled within a systematic probabilistic design. Where no motorized access exists, we employed a systematic design constrained by helicopter access and avalanche risk. Sixty-six sites were placed 5727 ± 1574 m (mean ± SD) apart; 30 were sampled in 2006–2007 and 36 in 2007–2008, for a total area of ~4200 km² sampled. Where motorized access exists, this systematic design was constrained by road and trail access. Fifty-four foothills sites were deployed 4335 ± 5218 m (mean ± SD) apart. We sampled from early December through March 2004–2005, and again in 2005–2006; the first year's data were used in abundance estimation only.

Hair samples were collected monthly from the barbed-wire hair traps using sterile techniques. Species were identified from follicular DNA (Wildlife Genetics International, Nelson, British Columbia, Canada). DNA was extracted from hairs using QIAGEN®'s DNEasy™ Tissue Kits (QIAGEN, Hilden, Germany) and analysed to identify species using sequence-based analysis of the 16S rRNA gene of mitochondrial DNA (mtDNA) (sensu Johnson and O'Brien 1997), then compared with a DNA reference library of known mammal species. Samples identified as wolverine were assayed using microsatellite analysis to identify unique individuals using seven microsatellite markers, a number considered adequate for genetic capture–mark–recapture studies (Paetkau 2004). We summed wolverine presences across 3 months (Dec.–Jan., Jan.–Feb., Feb.–Mar.) to yield a 0–3 count of species occurrences at each site—the dependent data for species distribution models. Monthly

Fig. 1. Presence (triangles) and absence (circles) of wolverines (*Gulo gulo luscus*) at 120 hair-trapping stations in the Front Ranges, Main Ranges, and Foothills of the Rocky Mountains of west-central Alberta, Canada. This landscape is a mosaic of high-elevation alpine patches, mid-elevation subalpine forests, and montane and foothills forests. The western portion of the study area is protected from anthropogenic development within the Willmore Wilderness Area (black border).



occurrences by individuals informed capture histories for abundance estimation models.

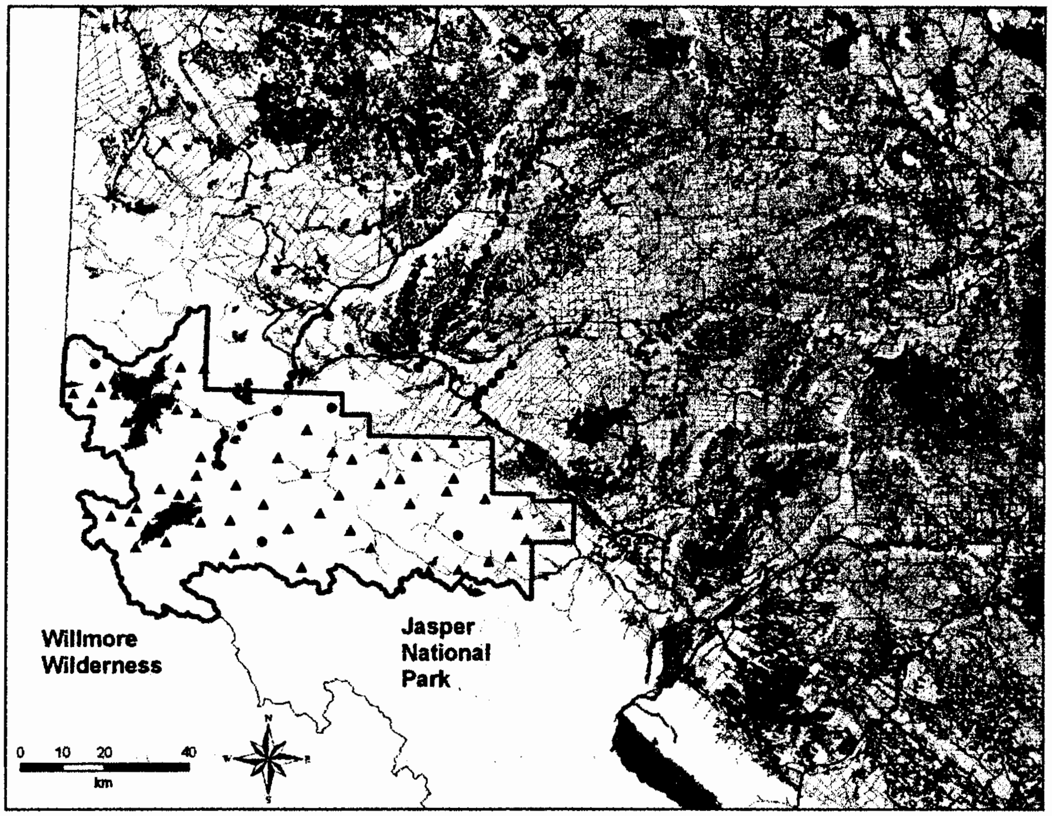
Abundance estimation

We used the Rcapture package (Baillargeon and Rivest 2007) in program R version 2.14.2 (R Development Core Team 2012) to estimate wolverine abundance. It is not feasible to relate abundance to the gradient of anthropogenic disturbance (since abundance is calculated for discrete areas, whereas the gradient is continuous). However, legislated landscape protection plays a role in the degree of disturbance (together with surface accessibility, existing land tenures, underlying geomorphology, and petroleum prices), so we asked whether wolverine abundance differed between the protected and the unprotected portions of the gradient. Models assumed a demographically closed population: mortality rates among a small population of large carnivores are expected to be near-zero over a 3-month period; our sampling period pre-dates mean kit emergence; dispersal occurs in this period (Inman et al. 2012), but there is no evidence that immigration differs from emigration. Rcapture calculates loglinear mark–recapture models (Cormack 1989) based on flexible assumptions of (*i*) no variation in hair-trap capture probability among individuals, M_0; (*ii*) variation in space, M_h; (*iii*) variation through time, M_t; (*iv*) variation in time and space, M_{th}; (*v*) behavioural variation resulting in a trap effect, M_b. Chao's (1987), Darroch et al.'s (1993), and Poisson (Rivest and Baillargeon 2007) model variants were also calculated. We selected the model with assumptions (heterogeneity, behaviour, temporal variability) that adequately fit the modelled data—a key requirement of abundance models (Baillargeon and Rivest 2007) that is reflected in low standard errors—balanced by model deviance and parsimony (Akaike's information criterion (AIC) score; Burnham and Anderson 2002). The foothills provided a sample size too small for mark–recapture analysis. Because wolverine detectability was the same in each study area (see Results), we could assume the ratio of detected animals inside and outside the Willmore approximated the ratio of total animals in these two areas and applied MacKenzie and Kendall's (2002) equation, which estimates relative abundances by adjusting for detection probabilities from occupancy models. In both cases, we divided the abundance estimate from this model by the estimated effective sampling area (e.g., Williams et al. 2002), calculated in GIS (ArcGIS version 9.3; ESRI, Inc., Redlands, California, USA) by buffering points in the sampling array with a 100 km² circle, approximating half a mean adult wolverine home range in Canadian mountain landscapes (Banci 1987, 1994).

Landscape quantification

Landscape composition (habitat availability) was quantified using a LandSat thematic-mapped GIS land-cover data set incorporating a digital elevation model, with a habitat-identification algorithm that classified 16 land-cover types (McDermid et al. 2009). Eight natural land-cover variables occurred sufficiently often in the study area to allow modelling: closed conifer forest, moderate conifer forest, open conifer forest, mixedwood forest, open wetland, upland shrubs, upland herbaceous habitats, and regenerating areas (for descriptions see McDermid et al. 2009). We calculated a topographic ruggedness index (TRI; Riley et al. 1999) based on a 25 m digital elevation model data from the Alberta Base Data set. Seismic line density (km/km²) obtained from government digital map inventory was used as a surrogate for anthropogenic habitat alteration and human activity. Seismic lines mark current and past oil and gas exploration, are correlated with current industrial activity (wellpads, drill sites, and pipelines), and provide recreational motorized access. They are also spatially

Fig. 2. Presence (triangles) and absence (circles) of wolverines (*Gulo gulo luscus*) at 120 hair-trapping stations in the Front Ranges, Main Ranges, and Foothills of the Rocky Mountains of west-central Alberta, Canada. The protected area of the Willmore Wilderness (black border) has two large burns (grey patches), whereas the landscape outside is a mosaic of trails and off-road motorized access, seismic lines for oil and gas development (thin lines), roads (thick lines), and forest harvesting (grey patches).



extensive, so lend themselves to modelling habitat alteration at large spatial scales. We used ArcGIS version 9.3 Spatial Analyst, spatial analysis routines, and the Regional Analysis function of Patch Analyst to calculate the percentage of each variable within a 5000 m radius buffer (78.5 km^2) around each sampling site. This area produces best-fit models for wolverines among a range of scales, and although some overlap among buffers exists, there is no evidence of inflation of type I error or biased estimates (Fisher et al. 2011).

Hierarchical occupancy modelling

Species detection is often imperfect and decreases with increasing rarity (MacKenzie et al. 2005, 2006). Species occupancy at a site (ψ) can be modelled in conjunction with its probability of detection (p): the probability of detecting that species if present (MacKenzie et al. 2006). If wolverine p differed between the design constraints (avalanche vs. trail), this might confound the habitat selection analysis. To ensure that data from across the entire study area could be reliably combined in generalized linear models for the habitat selection analysis, we tested whether p varied among design constraints, or through time, and whether significant landscape predictors of wolverine occupancy would mirror those from generalized linear models. We used custom single-season hierarchical occupancy models in software PRESENCE version 4.9 (Hines 2006). Detection histories comprised monthly wolverine detections and nondetections at each site, repeated across 3 months. Models assumed ψ was either constant, or varied with topographic ruggedness, seismic-line density, regenerating fire and cutblocks, or a combination of ruggedness and seismic-line density. Models further assumed that p was either constant, or differed among sampling constraints, or through time, or a combination of these. We ranked models by AIC weights and calculated evidence ratios (ERs) to weigh support for each covariate. From per-survey estimates of p, we calculated the probability of false absence (pfa) for a given survey duration as $(1 - p)^t$ (Long and Zielinski 2008), with $t = 3$ independent surveys.

Habitat selection

We used generalized linear models to test hypotheses about wolverines' relationship to landscape composition, since these are more flexible than occupancy models for this purpose. Because there were no differences in detectability among sites, the response variable was the frequency of monthly wolverine detections and nondetections at each site (0–3), across the study area. Habitat selection varies with habitat availability, and we had no a priori hypotheses about wolverines' relationships with natural landscape features in this landscape, with the exception of regenerating areas. To reduce the seven nondisturbance land-cover variables for model selection (Burnham and Anderson 2002), we used generalized linear models (Poisson errors, log link; *R* version 2.14.2) and the minimum adequate model approach (Crawley 2007) to identify which land-cover variables best explained wolverine occurrence data. The percentage of mixedwood forest was the only significant land-cover predictor. We additionally retained the "regenerating areas" variable—which included burned and harvested areas greater than ~10 years old—to test hypotheses about disturbed habitat. We then formulated 12 competing hypotheses about the importance of elevation, landscape ruggedness,

Fig. 3. Occurrence of wolverines (*Gulo gulo luscus*) was sampled with noninvasive genetic tagging via hair sampling in the Rocky Mountains of Alberta, Canada. Hair traps consisted of a tree loosely wrapped with barbed wire, baited with a large skinned beaver carcass and scent lure. Cameras placed on traps showed this method was effective at detecting wolverines.

mixedwood forest cover, seismic-line density, and regenerating areas in explaining wolverine occurrence (Table 1). We ranked models based on AIC scores and normalized AIC weights (which describe the weight of evidence in support of each model; Burnham and Anderson 2002). We summed AIC weights and calculated ERs (Anderson 2008) to summarize the overall importance of each variable in explaining wolverine occurrence; ER = 2 suggests there is twice the evidence for inclusion of an explanatory variable than its exclusion. We averaged the parameter estimates of the top models using R package MuMIn (Bartón 2012).

Results

Abundance

We identified 26 wolverines within the Willmore Wilderness Park (12 males, 14 females, at 66 sites), with overlapping space use (Fig. 4). The M_t model had low AIC score and low SE (1.3), estimating 27.2 wolverines. However, wolverine capture probability was heterogeneous and varied through time, thus fitting the M_{th} Chao model assumptions (Table 2), which estimated 28 wolverines (SE = 2.2) in this protected area. Other models' assumptions were unsupported by data, had higher AIC scores, or produced imprecise parameter estimates (Table 2). With 28 wolverines in an effective sampling area of 4140 km^2, we estimated density as 1 wolverine/148 km^2, or 6.8 wolverines/1000 km^2.

In the developed landscape to the east of the Willmore Wilderness, we detected five wolverines in year 1 (two males, three females, at 54 sites). Following pipeline installation through some sites, only three of these were detected in year 2 (Fig. 4). We estimated seven wolverines in this landscape in 2004–2005 and four wolverines in 2005–2006. With an effective sampling area of 2334 km^2 in 2004–2005, we estimated density as 1 wolverine/333 km^2, or 3 wolverines/1000 km^2. We sampled 2260 km^2 in 2005–2006 and estimated density as 1 wolverine/565 km^2, or 1.8 wolverines/1000 km^2.

Occupancy and probability of detection

Wolverine detectability did not vary between the two sampling design constraints. There was little evidence that p varied with sampling constraint alone (ER = 0.03) or with a combination of survey period and sampling constraint (ER = 0.37; Table 3). This evidence indicates that wolverines were equally detectable, when present, regardless of whether the systematic design was constrained by avalanche or road access. Equal detectability among sites justifies the use of combined data across the entire study area within species distribution models for habitat selection analysis. There was some evidence that the probability of wolverine detection increased January through March (ER = 1.22; Fig. 5). The best-supported model suggests that after 3 months of hair-trap surveys, there was an 87% probability of correctly assigning a site as occupied via hair-trapping (pfa = 0.13). Accounting for p, wolverines were more likely to occupy sites with increasingly rugged topography (ΣAIC weights = 0.70, ER = 2.31). There was weak evidence that occupancy varied with both ruggedness and seismic-line density (ΣAIC weights = 0.30, ER = 0.43). There was no evidence that wolverine occupancy varied with amount of regenerating area after timber harvest for fire (ER = 0.0).

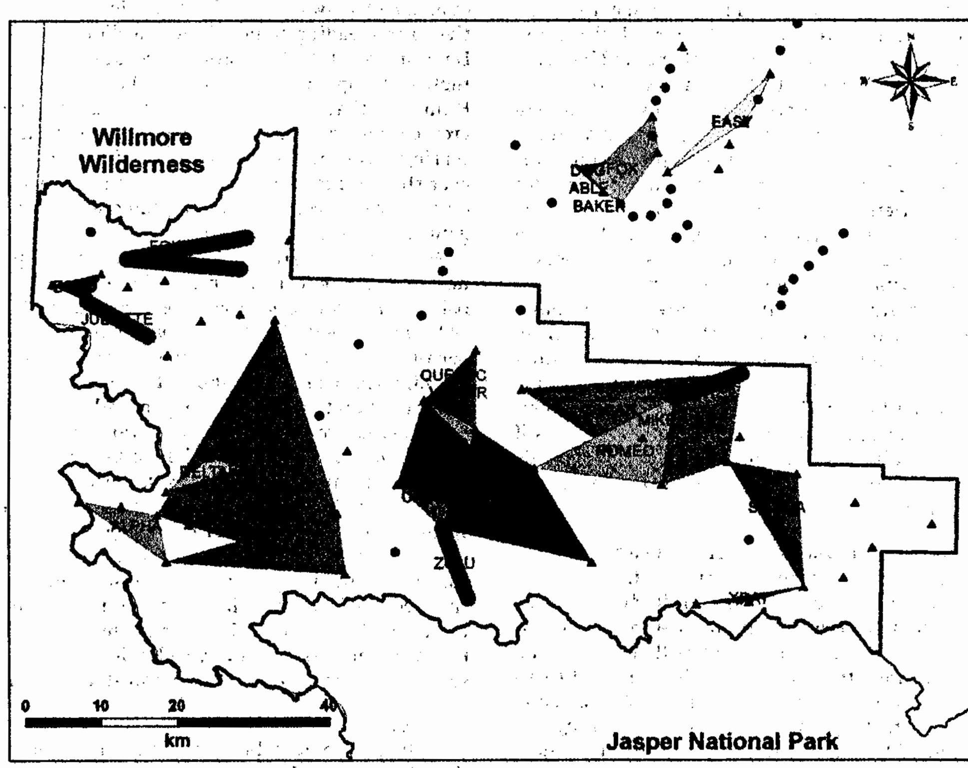
Habitat selection

Wolverines were more likely to occur in more topographically rugged terrain and areas where industrial activity and habitat

Table 1. Hypotheses about association of wolverines (*Gulo gulo luscus*) with features of the Alberta landscape and the corresponding models used to assess the explanatory variables.

Model	Hypothesis: wolverine occurrence is predicted by
1	Global model: proportion of mixedwood forest cover, proportion of regenerating areas, seismic-line density, landscape ruggedness, and sample-site elevation
2	Mixedwood forest cover, regenerating areas, seismic-line density, and landscape ruggedness
3	Mixedwood forest cover, regenerating areas, and seismic-line density
4	Mixedwood forest cover and regenerating areas
5	Regenerating areas only
6	Regenerating areas and seismic-line density
7	Regenerating areas, seismic-line density, and landscape ruggedness
8	Seismic-line density and landscape ruggedness
9	Landscape ruggedness only
10	Mixedwood forest and landscape ruggedness
11	Mixedwood forest and seismic-line density
12	Mixedwood forest, seismic-line density, and landscape ruggedness

Fig. 4. Minimum convex polygons (MCP) of "spatial detection ranges" of wolverine (*Gulo gulo luscus*) individuals (identified by names) detected at >1 site in the Main Ranges, Front Ranges, and Foothills of the Rocky Mountains of west-central Alberta, Canada. Twenty-six wolverines were detected within the Willmore Wilderness Park (black border); outside the Park, we detected 5 wolverines in 2004–2005 (shown) and only 3 of these again in 2005–2006. Wolverines were detected but not identified, or detected only once, at triangles outside MCPs and undetected at circles.



alteration was low. Wolverine occurrence was negatively related to seismic-line density (ER = 499) and was positively related to landscape ruggedness (ER = 61.5) (Table 4). Regenerating areas was related to wolverine occurrence (ER = 249), but this relationship is more difficult to decipher. The parameter estimate for REGEN was unstable in the multivariate model; it was negative in the single-variable model, but positive in the multi-variable model (Table 5), since regenerating areas and ruggedness were negatively correlated (see Caveats). Additional variables did not sufficiently improve explanatory power to warrant the penalty for an added parameter (Arnold 2010).

Discussion

Wolverine abundance differed between landscapes

The rugged, undeveloped end of the study area had 2–3 times the wolverine density of the less-rugged, developed end. By comparison, with 80% of the spatial effort (but twice the temporal effort) we identified only five wolverines outside the undeveloped Willmore Wilderness. Wolverine densities vary widely across western North America, ranging from 3 to 20 wolverines/1000 km^2, depending on location, trapping pressure, and habitat quality (Hornocker and Hash 1981; Banci and Harestad 1990; Lofroth and Krebs 2007; Golden et al. 2007; Inman et al. 2012). Many of these

Table 2. Estimated abundance of wolverines (*Gulo gulo luscus*) in the Rockies of west-central Alberta, based on Rcapture models with flexible assumptions of (*i*) no variation in hair-trap capture probability among individuals, M_0; (*ii*) variation among individuals only, M_h; (*iii*) variation through time, M_t; (*iv*) variation in time and individuals, M_{th}; (*v*) behavioural variation resulting in a trap effect, M_b; and Chao's (1987), Darroch et al.'s (1993), and Poisson (Rivest and Baillargeon 2007) model variants.

Model	Abundance estimate	SE	Model deviance	df	AIC score
M_0	27.8	1.7	17.09	5	39.72
M_t	27.2	1.3	6.58	3	33.21
M_b	51.7	38.0	4.36	4	28.99
M_{bh}	35.0	23.6	3.98	3	30.61
M_{th} Chao	28.2	2.2	4.75	2	33.38
M_{th} Darroch	33.2	10.9	4.75	2	33.38
M_{th} Poisson	30.0	4.7	4.75	2	33.38

Note: SE, standard error; df, degrees of freedom; AIC, Akaike's information criterion.

estimates are now 20–30 years old and none examines density estimates across landscapes with a marked gradient of habitat alteration. Our estimated 6.8 wolverines/1000 km² is similar to neighbouring British Columbia (6.2 wolverines/1000 km²; Lofroth and Krebs 2007) and Yukon (5.6 wolverines/1000 km²; Banci and Harestad 1990). The estimate of 2–3 wolverines/1000 km² is lower than most estimates from western North America, except for recent estimates from Montana (3.5 wolverines/1000 km²; Inman et al. 2012). The low density was unexpected, since wolverine populations have supported trapping throughout this region in past decades (Poole and Mowat 2001). Density differences inside and outside the protected area should be considered in the context of their close proximity (Fig. 3), which are <10–20 km apart in some places—much closer than wolverine home-range movements.

We used a standard method for estimating effective sampling area, but newly developed hierarchical models—which model encounter rates on spatial capture arrays as a basis for estimating effective sampling area—provide density estimates that sometimes differ from standard methods (Gardner et al. 2009). A hierarchical density estimator may have changed our conclusions if wolverine densities had differed only slightly inside and outside the park; however, the magnitude of the differences that we observed lends strong support to our conclusions.

Wolverines occupied rugged and undeveloped sites

Wolverines were more likely to occur at sites with rugged topography and low anthropogenic footprint. Similarly, May et al. (2006) found that Scandinavian wolverine home-range locations were better predicted by human infrastructure than by habitat. Wolverines avoid roads and other human development in British Columbia (Krebs et al. 2007), Norway (May et al. 2008), Idaho (Copeland et al. 2007), Montana (Carroll et al. 2001), and throughout the northwestern United States (Rowland et al. 2003). Inferences from range retractions coinciding with European colonization may also suggest wolverines are sensitive to human development at continental scales (Laliberte and Ripple 2004; Aubry et al. 2007).

We used seismic lines as an indicator of anthropogenic landscape alteration that causes habitat fragmentation and loss of forest canopy. Fragmentation is not synonymous with a barrier effect, as wolverines often cross these linear features (J.T. Fisher, unpublished snow-tracking data). Fragmentation can, however, alter ecological processes that indirectly affect species' distributions. We hypothesize that interspecific interactions play a role. Wolverines have a broad prey base (Hornocker and Hash 1981; Banci and Harestad 1990; Lofroth et al. 2007) including caribou neonates (Gustine et al. 2006), but reproductive rates are driven by winter availability of ungulate carcasses (Persson 2005). Anthropogenic activity may provide predation refuges for ungulates (e.g., Muhly et al. 2011) thereby reducing carcass availability. Alternatively, competition among carnivores may increase with fragmentation and human activity; seismic lines can alter movement by wolves (*Canis lupus* L., 1758), increasing encounter rates with other species and predation rates (James and Stuart-Smith 2000; Whittington et al. 2005; McKenzie et al. 2012), a factor implicated in the declines of Alberta woodland caribou (*Rangifer tarandus caribou* (Gmelin, 1788)) (e.g., Sorensen et al. 2008; Schneider et al. 2010). Seismic lines may therefore increase competition or intraguild predation for wolverines. In Scandinavia, wolves and Eurasian lynx (*Lynx lynx* (L., 1758)) are important influences on wolverine habitat selection (Mattisson et al. 2011*a*, 2011*b*; van Dijk et al. 2008*a*, 2008*b*). However, interspecific processes have never been examined in the markedly more predator-diverse North American landscape, where wolverines coexist with multiple ursid, canid, felid, and large mustelid species (Fisher et al. 2011); this remains a significant gap.

Habitat alteration and accompanying human activity may degrade habitat quality and depress naturally late-onset reproduction, low reproductive rates, juvenile survival, and population growth rates (Banci and Harestad 1988; Krebs et al. 2004; Persson et al. 2006). Low adult survival in harvested populations (Krebs et al. 2004) shows that anthropogenic mortality is typically additive, often leading to population declines (Lofroth and Ott 2007; Dalerum et al. 2008). Natural predation on wolverines is also higher in trapped than untrapped landscapes (Krebs et al. 2004). Human activity may therefore increase mortality through increased natural or human predation, alternatively denning and rearing areas may be abandoned owing to perceived risk. Whatever the mechanism, we show that the probability of wolverine occurrence decreases across a gradient of increasing anthropogenic landscape development.

Wolverine occurrence also increases with topographic ruggedness, where there is a combination of low- and high-elevation habitats. Bighorn sheep (*Ovis canadensis* Shaw, 1804) (Festa-Bianchet 1988), mule deer (*Odocoileus hemionus* (Rafinesque, 1817)) (D'Eon and Serrouya 2005), and other ungulates winter at lower elevations; in Scandinavia, wolverines showed significant selection for lower-elevation habitats during winter months (Landa et al. 1998). It is possible that wolverines require lower elevations for foraging and higher elevations for predation refuge. Persistent spring snow cover has been hypothesized as important (Schwartz et al. 2009; Copeland et al. 2010) but is not a good predictor at this scale, since spring snow cover was sufficiently persistent across our study landscape to prevent modelling but wolverine occurrence still varied. Finally, rugged areas may offer more den sites in steep, snow-covered slopes with large talus boulders (Magoun and Copeland 1998) and such den sites may be limiting factors for breeding females. However, wolverines also den in flatter landscapes in lower foothills, boreal forest, and arctic tundra.

Caveats

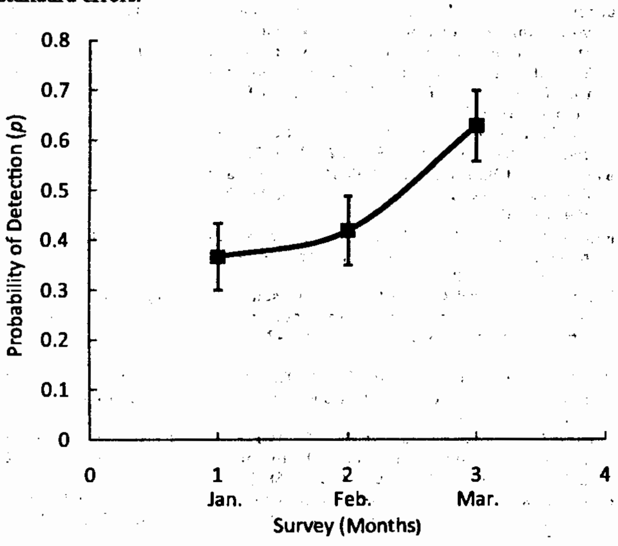
Wolverine detectability was imperfect and varied through time. For large mobile organisms, detectability is affected by movement in and out of sites that is assumed to be non-Markovian (Mackenzie et al. 2006). Variable wolverine detectability could result from changes in mobility owing to snow conditions or female denning (which occurs in this period). Understanding the relationship between mobility and detectability is an ongoing area of research. Notably, if wolverine detectability had differed among design constraints—avalanche risk vs. trail access—then estimates from species distribution models could be affected. In fact, all evidence from occupancy models showed that there was no effect of design constraint on wolverine detectability, indicating that the results observed from habitat selection models (which used the same data) were due to ecological signal, not an artefact of sampling, providing confidence in the conclusions.

Table 3. Selection of wolverine (*Gulo gulo luscus*) occupancy models in west-central Alberta.

Model	AIC	ΔAIC	AIC weight	Model likelihood	No. of parameters*	−2(log likelihood)
ψ(RUGGED),p(SURVEY)	298.96	0.00	0.38	1.00	5.00	288.96
ψ(RUGGED),p(SURVEY+CONSTRAINT)	299.71	0.75	0.26	0.69	6.00	287.71
ψ(RUGGED+SEISMIC),p(SURVEY)	300.56	1.60	0.17	0.45	6.00	288.56
ψ(RUGGED+SEISMIC),p(SURVEY+CONSTRAINT)	301.50	2.54	0.11	0.28	7.00	287.50
ψ(RUGGED),p(.)	303.79	4.83	0.03	0.09	3.00	297.79
ψ(RUGGED),p(CONSTRAINT)	304.54	5.58	0.02	0.06	4.00	296.54
ψ(RUGGED+SEISMIC),p(.)	305.41	6.45	0.02	0.04	4.00	297.41
ψ(RUGGED+SEISMIC),p(CONSTRAINT)	306.36	7.40	0.01	0.02	5.00	296.36
ψ(SEISMIC),p(SURVEY+CONSTRAINT)	315.83	16.87	0.00	0.00	6.00	303.83
ψ(SEISMIC),p(SURVEY)	318.38	19.42	0.00	0.00	5.00	308.38
ψ(.),p(SURVEY+CONSTRAINT)	319.44	20.48	0.00	0.00	5.00	309.44
ψ(SEISMIC),p(CONSTRAINT)	320.31	21.35	0.00	0.00	4.00	312.31
ψ(REGEN),p(SURVEY+CONSTRAINT)	320.42	21.46	0.00	0.00	6.00	308.42
ψ(SEISMIC),p(.)	323.10	24.14	0.00	0.00	3.00	317.10
ψ(.),p(CONSTRAINT)	323.77	24.81	0.00	0.00	3.00	317.77
ψ(REGEN),p(CONSTRAINT)	324.80	25.84	0.00	0.00	4.00	316.80
ψ(REGEN),p(SURVEY)	352.11	53.15	0.00	0.00	5.00	342.11
ψ(.),p(SURVEY)	356.05	57.09	0.00	0.00	4.00	348.05
ψ(REGEN),p(.)	356.80	57.84	0.00	0.00	3.00	350.80
ψ(.),p(.)	360.67	61.71	0.00	0.00	2.00	356.67

Note: Occupancy (ψ) could be constant (.), vary with topographic RUGGEDness, SEISMIC line density, or REGENerating forest fires and cutblocks within a 5 km radius. Probability of detection (p) could differ by sampling design CONSTRAINTs or among SURVEYs.
*Number of estimated β parameters in the model.

Fig. 5. Wolverines (*Gulo gulo luscus*) were imperfectly detected via hair trapping in the mountain landscape of west-central Alberta, Canada. The probability of detecting wolverines, when present at a site, increased monthly from Dec. through Mar. After three surveys, the probability of false absence was reduced to ~13%. Bars represent standard errors.



After accounting for differences in land cover and topography, developed landscapes with human activity resulted in fewer wolverines across this natural and anthropogenic gradient spanning 30 individuals and an area in excess of 6000 km².

Topography and habitat alteration are unavoidably correlated on this edge of wolverines' distribution. Rugged areas are less likely to be developed, and topographic ruggedness was negatively correlated with both seismic-line density (Pearson's $r = -0.765$, $p < 0.0001$) and regenerating areas (Pearson's $r = -0.503$, $p < 0.0001$). Sampling design could not avoid this correlation, as no large tracts of undeveloped areas remain in subalpine and foothills landscapes (Fig. 2), and the alpine remains primarily undeveloped. This begs the question: is topography masking some signal from anthropogenic development, or vice versa? Generalized linear modelling provided strong evidence that this correlation does not obfuscate the signal that we detected, as the effects of seismic-line density and regenerating areas remained even after accounting for topographic ruggedness (model 9 vs. model 7, ΔAIC = 17.33; Table 5). If otherwise, model ΔAIC scores would be smaller, and relative support for either the habitat alteration or the ruggedness models weaker, as they share variance. Instead, ΔAIC and evidence ratios are high—strong support for including both seismic-line density and topography in the model. Hierarchical models provided similar evidence, though the effect of habitat alteration was weaker because some of the variance was attributed to temporal changes in detectability. The response of wolverines to regenerating areas requires more investigation, as multicollinearity among variables changed the direction of this relationship in our models.

Implications for wolverine landscape ecology

Wolverine occurrence decreases with increasing anthropogenic landscape development at this range margin, and wolverine density changes very abruptly. Alone, the 30 wolverines in the protected landscape would not likely persist long term (e.g., Reed et al. 2003; Traill et al. 2010), but Alberta wolverines' high genetic variability indicates that they are connected to, and exchanging DNA within, a larger population (Kyle and Strobeck 2001, 2002). However, connectivity may prove detrimental. To the west, wolverines are overharvested and in decline (Lofroth and Ott 2007) and are subject to anthropogenic habitat loss (Krebs et al. 2007). If in addition anthropogenic habitat alteration at the eastern range margin creates a population sink (sensu Pulliam 1988; Pulliam and Danielson 1991), together these may result in population decline. Moreover, though Rocky Mountain wolverine densities are (comparatively) high, density does not equal quality (Wheatley et al. 2002); Brøseth et al. (2010) suggest wolverine population growth rates can decrease as density increases.

We have shown a large-scale spatial correlation between wolverine occurrence and habitat fragmentation on this edge of their range. If fragmentation is altering ecological processes resulting in reduced wolverine distribution and wolverine declines, then identifying the mechanisms responsible should be the next target for investigation. As wolverines exist at very low densities, and

Table 4. Selection of wolverine (*Gulo gulo luscus*)–habitat models in west-central Alberta.

Model	Habitat variables	Residual deviance*	Residual df	AIC score	ΔAIC	AIC weight
7	REGEN+SEISMIC+RUGGED	90.4	116	220.23	0	0.539
2	MIXED+REGEN+SEISMIC+RUGGED	89.5	115	221.32	1.09	0.312
1	MIXED+REGEN+SEISMIC+RUGGED+ELEV	89.2	114	223.02	2.79	0.133
3	MIXED+REGEN+SEISMIC	98.4	116	228.19	7.96	0.010
6	REGEN+SEISMIC	103.8	117	231.67	11.44	0.002
12	MIXED+SEISMIC+RUGGED	102.0	116	231.79	11.56	0.002
8	SEISMIC+RUGGED	104.5	117	232.32	12.09	0.001
10	MIXED+RUGGED	105.1	117	232.90	12.67	0.001
11	MIXED+SEISMIC	108.2	117	236.05	15.82	0.000
9	RUGGED	111.7	118	237.56	17.33	0.000
4	MIXED+REGEN	119.7	117	247.49	25.52	0.000
5	REGEN	152.9	118	278.75	27.26	0.000

Note: AIC, Akaike's information criterion. MIXED is the proportion of area in mixedwood (co-dominant deciduous and coniferous); REGEN is the proportion of area regenerating (fires and cutblocks <20 years old); SEISMIC is the seismic-line density in kilometres of seismic line per square kilometre of area; RUGGED is the topographic ruggedness index; ELEV is the elevation of the sample site (metres above sea level). Wolverine occurrence counts were modeled against GIS habitat data measured at a 5000 m radius using generalized linear models. The best-supported model suggests regenerating areas, seismic-line density, and topographic ruggedness best explain wolverine occurrence.

*Null model deviance is 161.7 on 119 degrees of freedom (df).

Table 5. Estimated β parameters from wolverine (*Gulo gulo luscus*) species distribution models.

Model	Parameter	Estimate	SE	*p*	RVI*
7, 2 averaged	Intercept	−3.074	1.082	0.0049	
	REGEN	6.225	1.806	0.0006	1.00
	SEISMIC	−1.874	0.546	0.0007	1.00
	RUGGED	0.002	0.001	0.0013	1.00
	MIXED	−2.692	2.974	0.3704	0.35
5	Intercept	−0.231	0.115	0.0438	
	REGEN	−1.457	0.754	0.0534	

Note: Generalized linear models of wolverine occurrence in foothills and mountain landscapes suggest wolverines were positively predicted by topographic ruggedness and negatively predicted by seismic-line density, regenerating areas, and mixedwood forest. SE, standard error.

*Relative variable importance (RVI) is the sum of AIC weights over all models (Bartón 2012).

over vast areas, and across landscapes with markedly different ecological characteristics and disturbance regimes, multiple inferences from landscape-scale studies will be needed to derive the ecological mechanisms caused by human use of shared landscapes.

Acknowledgements

Research was funded by Alberta Innovates – Technology Futures (AITF), Alberta Conservation Association, and the Government of Alberta – Parks Division, with support from Alberta Environment and Sustainable Resource Development. AITF, Natural Sciences and Engineering Research Council of Canada (NSERC), University of Victoria, and MITACS provided grants to J.T.F. The Foundation for North American Wild Sheep and the Manning Forestry Research Fund provided additional funds. Parks Canada and Hinton Wood Products (Division of West Fraser) provided in-kind support. Thanks go to L. Peleshok, C. Twitchell, S. Newman, S. Gervais, E. Cannan, G. Glover, C. Morrison, K. Vujnovic, and many who collected data and supported logistics. M. Hiltz, D. Pan, A. Leyne, K. Killistoff, and D. Mucha provided additional analyses. A. Fisher, L. Wilkinson, A. Magoun, E. Lofroth, R. Mulders, D. Paetkau, M. Jokinen, and D. Vujnovic provided valuable advice.

References

Alberta Fish and Wildlife Division. 2008. Report of Alberta's Endangered Species Conservation Committee, June 2006. Alberta SRD, FWD, Edmonton.

Amstrup, S.C., McDonald, T.L., and Manly, B.F. 2010. Handbook of capture–recapture analysis. Princeton University Press, Princeton, N.J.

Anderson, D.R. 2008. Model based inference in the life sciences: a primer on evidence. Springer-Verlag, New York.

Arnold, T.W. 2010. Uninformative parameters and model selection using Akaike's information criterion. J. Wildl. Manage. **74**: 1175–1178. doi:10.2193/2009-367.

Aubry, K.B., McKelvey, K.S., and Copeland, J.P. 2007. Distribution and broadscale habitat relations of the wolverine in the contiguous United States. J. Wildl. Manage. **71**: 2147–2158. doi:10.2193/2006-548.

Baillargeon, S., and Rivest, L.-P. 2007. Rcapture: loglinear models for capture–recapture in R. J. Stat. Soft. **19**: 1–31.

Banci, V.A. 1987. Ecology and behavior of wolverine in Yukon. M.Sc. thesis, Simon Fraser University, Burnaby, B.C.

Banci, V.A. 1994. Wolverine. *In* The scientific basis for conserving forest carnivores, American marten, fisher, lynx, and wolverine in the western United States. *Edited by* L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. Gen. Tech. Rep. No. RM-254, United States Department of Agriculture, Forest Service, Rocky Mountain Range Experiment Station, Fort Collins, Colo. pp. 99–127.

Banci, V., and Harestad, A.S. 1988. Reproduction and natality of wolverine (*Gulo gulo*) in Yukon. Ann. Zool. Fenn. **25**: 265–270.

Banci, V., and Harestad, A.S. 1990. Home range and habitat use of wolverines *Gulo gulo* in Yukon, Canada. Holarct. Ecol. **13**: 195–200. doi:10.1111/j.1600-0587.1990.tb00608.x.

Bartón, K. 2012. MuMIn: Multi-model inference. R package version 1.7.2 [computer program]. Available from http://CRAN.R-project.org/package=MuMIn [accessed 7 June 2013].

Brøseth, H., Flagstad, Ø., Wärdig, C., Johansson, M., and Ellegren, H. 2010. Large-scale noninvasive genetic monitoring of wolverines using scats reveals density dependent survival. Biol. Conserv. **143**: 113–120. doi:10.1016/j.biocon.2009.09.012.

Burnham, K.P., and Anderson, D.R. 2002. Model selection and multimodel inference: a practical information–theoretic approach. 2nd ed. Springer-Verlag, New York.

Carroll, C., Noss, R.F., and Paquet, P.C. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecol. Appl. **11**: 961–980. doi:10.1890/1051-0761(2001)011[0961:CAFSFC]2.0.CO;2.

Chao, A. 1987. Estimating the population size for capture–recapture data with unequal catchability. Biometrics, **43**: 783–791. doi:10.2307/2531532. PMID: 3427163.

Copeland, J.P., Peek, J.M., Groves, C.R., Melquist, W.E., McKelvey, K.S., McDaniel, G.W., Long, C.D., and Harris, C.E. 2007. Seasonal habitat associations of the wolverine in central Idaho. J. Wildl. Manage. **71**: 2201–2212. doi:10.2193/2006-559.

Copeland, J.P., McKelvey, K.S., Aubry, K.B., Landa, A., Persson, J., Inman, R.M., Krebs, J., Lofroth, E., Golden, H., Squires, J.R., Magoun, A., Schwartz, M.K., Wilmot, J., Copeland, C.L., Yates, R.E., Kojola, I., and May, R. 2010. The bioclimatic envelope of the wolverine (*Gulo gulo*): do climatic constraints limit its geographic distribution? Can. J. Zool. **88**(3): 233–246. doi:10.1139/Z09-136.

Cormack, R.M. 1989. Log-linear models for capture–recapture. Biometrics, **45**: 395–413. doi:10.2307/2531485.

Crawley, M. 2007. The R book. John Wiley and Sons Ltd., Chichester, U.K.

Dalerum, F., Shults, B., and Kunkel, K. 2008. Estimating sustainable harvest in wolverine populations using logistic regression. J. Wildl. Manage. **72**: 1125–1132. doi:10.2193/2007-336.

Darroch, J.N., Fienberg, S.E., Glonek, G.F.V., and Junker, B.W. 1993. A three-sample multiple-recapture approach to census population estimation with heterogeneous catchability. J. Am. Stat. Assoc. 88: 1137–1148. doi:10.1080/01621459.1993.10476387.

D'Eon, R.G., and Serrouya, R. 2005. Mule deer seasonal movements and multiscale resource selection using global positioning system radiotelemetry. J. Mammal. 86: 736–744. doi:10.1644/1545-1542(2005)086[0736:MDSMAM]2.0.CO;2.

Downing, D.J., and Pettapiece, W.W. 2006. Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Publ. No. T/852. Government of Alberta, Edmonton.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. J. Wildl. Manage. 61: 603–610. doi:10.2307/3802168.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34: 487–515. doi:10.1146/annurev.ecolsys.34.011802.132419.

Festa-Bianchet, M. 1988. Seasonal range selection in bighorn sheep: conflicts between forage quality, forage quantity, and predator avoidance. Oecologia, 75: 580–586. doi:10.1007/BF00776423.

Fisher, J.T., and Wilkinson, L. 2005. The response of mammals to forest fire and timber harvest in the North American boreal forest. Mammal Rev. 35: 51–81. doi:10.1111/j.1365-2907.2005.00053.x.

Fisher, J.T., Boutin, S., and Hannon, S.J. 2005. The protean relationship between boreal forest landscape structure and red squirrel distribution at multiple spatial scales. Landsc. Ecol. 5: 73–82. doi:10.1007/s10980-004-0677-1.

Fisher, J.T., Anholt, B., and Volpe, J.P. 2011. Body mass explains characteristic scales of habitat selection in terrestrial mammals. Ecol. Evol. 1: 517–528. doi:10.1002/ece3.45. PMID:22393519.

Fisher, J.T., Anholt, B., Bradbury, S., Wheatley, M., and Volpe, J.P. 2012. Spatial segregation of sympatric marten and fishers: the influence of landscapes and species-scapes. Ecography, 35: 1–9. doi:10.1111/j.1600-0587.2012.07556.x.

Flagstad, Ø., Hedmark, E., Landa, A., Brøseth, H., Persson, J., Andersen, R., Segerstrom, P., and Ellegren, H. 2004. Colonization history and noninvasive monitoring of a re-established wolverine population. Conserv. Biol. 18: 676–688. doi:10.1111/j.1523-1739.2004.00328.x-i1.

Franklin, J., and Miller, J.A. 2009. Mapping species distributions: spatial inference and prediction. Cambridge University Press, Cambridge, U.K.

Gardner, B., Royle, J.A., and Wegan, M.T. 2009. Hierarchical models for estimating density from DNA mark-recapture studies. Ecology, 90: 1106–1115. doi:10.1890/07-2112.1. PMID:19449704.

Golden, H.N., Henry, J.D., Becker, E.F., Goldstein, M.I., Morton, J.M., Frost, D., Sr., and Poe, A.J. 2007. Estimating wolverine *Gulo gulo* population size using quadrat sampling of tracks in snow. Wildl. Biol. 13(Suppl. 2): 52–61.

Gustine, D.D., Parker, K.L., Lay, R.J., Gillingham, M.P., and Heard, D.C. 2006. Calf survival of woodland caribou in a multi-predator ecosystem. Wildl. Monogr. 165: 1–32. doi:10.2193/0084-0173(2006)165[1:CSOWCI]2.0.CO;2.

Hedmark, E., and Ellegren, H. 2007. DNA-based monitoring of two newly founded Scandinavian wolverine populations. Conserv. Genet. 8: 843–852. doi:10.1007/s10592-006-9231-9.

Hines, J.E. 2006. PRESENCE—Estimates patch occupancy and related parameters. Version 3.0 Build 100317.0949 Beta [computer program]. USGS-PWRC. Available at http://www.mbr-pwrc.usgs.gov/software/presence.html [accessed 13 June 2013].

Hornocker, M.G., and Hash, H.S. 1981. Ecology of the wolverine in northwestern Montana. Can. J. Zool. 59(7): 1286–1301. doi:10.1139/z81-181.

Inman, R.M., Packila, M.L., Inman, K.H., McCue, A.J., White, G.C., Persson, J., Aber, B.C., Orme, M.L., Alt, K.L., Cain, S.L., Fredrick, J.A., Oakleaf, B.J., and Sartorius, S.S. 2012. Spatial ecology of wolverines at the southern periphery of distribution. J. Wildl. Manage. 76: 778–792. doi:10.1002/jwmg.289.

James, A.R.C., and Stuart-Smith, A.K. 2000. Distribution of caribou and wolves in relation to linear corridors. J. Wildl. Manage. 64: 154–159. doi:10.2307/3802985.

Johnson, W., and O'Brien, S.J. 1997. Phylogenetic reconstruction of the Felidae using 16S rRNA and NADH-5 mitochondrial genes. J. Mol. Evol. 44(Suppl. 1): S98–S116. doi:10.1007/PL00000060.

Kendall, K.C., and McKelvey, K.S. 2008. Hair collection. *In* Noninvasive survey methods for carnivores. *Edited by* R. Long, P. Mackay, J. Ray, and W. Zielinski. Island Press, Washington, D.C. pp. 141–182.

Krebs, J., Lofroth, E., Copeland, J., Banci, V., Cooley, D., Golden, H., Magoun, A., Mulders, R., and Shults, B. 2004. Synthesis of survival rates and causes of mortality in North American wolverines. J. Wildl. Manage. 68: 493–502. doi:10.2193/0022-541X(2004)068[0493:SOSRAC]2.0.CO;2.

Krebs, J., Lofroth, E.C., and Parfitt, I. 2007. Multiscale habitat use by wolverines in British Columbia, Canada. J. Wildl. Manage. 71: 2180–2192. doi:10.2193/2007-099.

Kyle, C.J., and Strobeck, C. 2001. Genetic structure of North American wolverine (*Gulo gulo*) populations. Mol. Ecol. 10: 337–347. doi:10.1046/j.1365-294x.2001.01222.x. PMID:11298949.

Kyle, C.J., and Strobeck, C. 2002. Connectivity of peripheral and core populations of North American wolverines. J. Mammal. 83: 1141–1150. doi:10.1644/1545-1542(2002)083<1141:COPACP>2.0.CO;2.

Laliberte, A.S., and Ripple, W.J. 2004. Range contractions of North American carnivores and ungulates. BioScience, 54: 123–138. doi:10.1641/0006-3568(2004)054[0123:RCONAC]2.0.CO;2.

Landa, A., Strand, O., Linnell, J.D.C., and Skogland, T. 1998. Home-range sizes and altitude selection for arctic foxes and wolverines in an alpine environment. Can. J. Zool. 76(3): 448–457. doi:10.1139/z97-209.

Lofroth, E.C., and Krebs, J. 2007. The abundance and distribution of wolverines in British Columbia, Canada. J. Wildl. Manage. 71: 2159–2169. doi:10.2193/2007-094.

Lofroth, E.C., and Ott, P.K. 2007. Assessment of the sustainability of wolverine harvest in British Columbia, Canada. J. Wildl. Manage. 71: 2193–2200. doi:10.2193/2007-095.

Lofroth, E.C., Krebs, J.A., Harrower, W.L., and Lewis, D. 2007. Food habits of wolverine *Gulo gulo* in montane ecosystems of British Columbia, Canada. Wildl. Biol. 13(Suppl. 2): 31–37. doi:10.2981/0909-6396(2007)13[31:FHOWGG]2.0.CO;2.

Long, R., and Zielinski, W. 2008. Designing effective noninvasive carnivore surveys. *In* Noninvasive survey methods for carnivores. *Edited by* R. Long, P. Mackay, J. Ray, and W. Zielinski. Island Press, Washington, D.C. pp. 8–44.

MacKenzie, D.I., and Kendall, W.L. 2002. How should detection probability be incorporated into estimates of relative abundance? Ecology, 83: 2387–2393. doi:10.1890/0012-9658(2002)083[2387:HSDPBI]2.0.CO;2.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A., and Langtimm, C.A. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology, 83: 2248–2255. doi:10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2.

MacKenzie, D.I., Nichols, J.D., Sutton, N., Kawanishi, K., and Bailey, L.L. 2005. Improving inferences in population studies of rare species that are detected imperfectly. Ecology, 86: 1101–1113. doi:10.1890/04-1060.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L., and Hines, J.E. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, New York.

Magoun, A.J., and Copeland, J.P. 1998. Characteristics of wolverine reproductive den sites. J. Wildl. Manage. 62: 1313–1320. doi:10.2307/3801996.

Magoun, A.J., Long, C.D., Schwartz, M.K., Pilgrim, K.L., Lowell, R.E., and Valkenburg, P. 2011. Integrating motion-detection cameras and hair snags for wolverine identification. J. Wildl. Manage. 75: 731–739. doi:10.1002/jwmg.107.

Mattisson, J., Andrén, H., Persson, J., and Segerström, P. 2011*a*. Influence of intraguild interactions on resource use by wolverines and Eurasian lynx. J. Mammal. 92(6): 1321–1330. doi:10.1644/11-MAMM-A-099.1.

Mattisson, J., Persson, J., Andrén, H., and Segerström, P. 2011*b*. Temporal and spatial interactions between an obligate predator, the Eurasian lynx (*Lynx lynx*), and a facultative scavenger, the wolverine (*Gulo gulo*). Can. J. Zool. 89(2): 79–89. doi:10.1139/Z10-097.

May, R., Landa, A., van Dijk, J., Linnell, J.D.C., and Andersen, R. 2006. Impact of infrastructure on habitat selection of wolverines *Gulo gulo*. Wildl. Biol. 12: 285–295. doi:10.2981/0909-6396(2006)12[285:IOIOHS]2.0.CO;2.

May, R., van Dijk, J., Wabakken, P., Swenson, J.E., Linnell, J.D.C., Zimmermann, B., Odden, J., Pedersen, H.C., Andersen, R., and Landa, A. 2008. Habitat differentiation within the large-carnivore community of Norway's multiple-use landscapes. J. Appl. Ecol. 45: 1382–1391. doi:10.1111/j.1365-2664.2008.01527.x. PMID:19330031.

McDermid, G.J., Hall, R.J., Sanchez-Azofeifa, G.A., Franklin, S.E., Stenhouse, G.B., Kobliuk, T., and LeDrew, E.F. 2009. Remote sensing and forest inventory for wildlife habitat assessment. For. Ecol. Manage. 257: 2262–2269. doi:10.1016/j.foreco.2009.03.005.

McKenzie, H.W., Merrill, E.H., Spiteri, R.J., and Lewis, M.A. 2012. How linear features alter predator movement and the functional response. Interface Focus, 2(2): 205–216. doi:10.1098/rsfs.2011.0086.

Muhly, T.B., Semeniuk, C., Massolo, A., Hickman, L., and Musiani, M. 2011. Human activity helps prey win the predator–prey space race. PLoS ONE, 6: e17050. doi:10.1371/journal.pone.0017050. PMID:21399682.

Mulders, R., Boulanger, J., and Paetkau, D. 2007. Estimation of population size for wolverines *Gulo gulo* at Daring Lake, Northwest Territories, using DNA based mark–recapture methods. Wildl. Biol. 13(Suppl. 2): 38–51. doi:10.2981/0909-6396(2007)13[38:EOPSFW]2.0.CO;2.

Paetkau, D. 2004. The optimal number of markers in genetic capture–mark–recapture studies. J. Wildl. Manage. 68: 449–452. doi:10.2193/0022-541X(2004)068[0449:TONOMI]2.0.CO;2.

Pasitschniak-Arts, M., and Larivière, S. 1995. *Gulo gulo*. Mamm. Species, 499: 1–10.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends Ecol. Evol. 10: 430. doi:10.1016/S0169-5347(00)89171-5. PMID:21237093.

Persson, J. 2005. Female wolverine (*Gulo gulo*) reproduction: reproductive costs and winter food availability. Can. J. Zool. 83(11): 1453–1459. doi:10.1139/z05-143.

Persson, J., Landa, A., Andersen, R., and Segerström, P. 2006. Reproductive characteristics of female wolverines (*Gulo gulo*) in Scandinavia. J. Mammal. 87: 75–79. doi:10.1644/04-.1.

Persson, J., Ericsson, G., and Segerström, P. 2009. Human caused mortality in the endangered Scandinavian wolverine population. Biol. Conserv. 142: 325–331. doi:10.1016/j.biocon.2008.10.028.

Petersen, S. 1997. Status of the Wolverine, *Gulo gulo*, in Alberta. Wildlife Status Report No. 2, Alberta Environmental Protection, Wildlife Management Division, Edmonton.

Poole, K., and Mowat, G. 2001. Alberta Furbearer Harvest Data Analysis. Alberta Species at Risk Report No. 31, Alberta Sustainable Resource Development, Fish and Wildlife Division, Edmonton.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. Am. Nat. 132: 652–661. doi:10.1086/284880.

Pulliam, H.R., and Danielson, B.J. 1991. Sources, sinks, and habitat selection: a landscape perspective on population dynamics. Am. Nat. 137(Suppl. 1): S5–S66. doi:10.1086/285139.

R Development Core Team. 2012. R: a language and environment for statistical computing. Version 2.14.2 [computer program]. R Foundation for Statistical Computing, Vienna, Austria. Available from http://www.r-project.org/.

Reed, D.H., O'Grady, J.J., Brook, B.W., Ballou, J.D., and Frankham, R. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biol. Conserv. 113: 23–34. doi:10.1016/S0006-3207(02)00346-4.

Riley, S.J., DeGloria, S.D., and Elliot, R. 1999. A terrain ruggedness index that quantifies topographic heterogeneity. Intermountain J. Sci. 5: 1–4.

Rivest, L.P., and Baillargeon, S. 2007. Applications and extensions of Chao's moment estimator for the size of a closed population. Biometrics, 63: 999–1006. doi:10.1111/j.1541-0420.2007.00779.x. PMID:17425635.

Rowland, M.M., Wisdom, M.J., Johnson, D.H., Wales, B.C., Copeland, J.P., and Edelmann, F.B. 2003. Evaluation of landscape models for wolverines in the interior Northwest, United States of America. J. Mammal. 84: 92–105. doi:10.1644/1545-1542(2003)084<0092:EOLMFW>2.0.CO;2.

Schneider, R.R., Stelfox, J.B., Boutin, S., and Wasel, S. 2003. Managing the cumulative impacts of land-uses in the Western Canadian Sedimentary Basin: a modeling approach. Conserv. Ecol. 7: 8.

Schneider, R.R., Hauer, G., Adamowicz, W.L., and Boutin, S. 2010. Triage for conserving populations of threatened species: the case of woodland caribou in Alberta. Biol. Conserv. 143: 1603–1611. doi:10.1016/j.biocon.2010.04.002.

Schwartz, M.K., Copeland, J.P., Anderson, N.J., Squires, J.R., Inman, R.M., McKelvey, K.S., Pilgrim, K.L., Waits, L.P., and Cushman, S.A. 2009. Wolverine gene flow across a narrow climatic niche. Ecology, 90: 3222–3232. doi:10.1890/08-1287.1. PMID:19967877.

Sorensen, T., McLoughlin, P.D., Hervieux, D., Dzus, E., Nolan, J., Wynes, B., and Boutin, S. 2008. Determining sustainable levels of cumulative effects for boreal caribou. J. Wildl. Manage. 72: 900–905. doi:10.2193/2007-079.

Traill, L.W., Brook, B.W., Frankham, R.R., and Bradshaw, C.J.A. 2010. Pragmatic population viability targets in a rapidly changing world. Biol. Conserv. 143: 28–34. doi:10.1016/j.biocon.2009.09.001.

van Dijk, J., Andersen, T., May, R., Andersen, R., Andersen, R., and Landa, A. 2008a. Foraging strategies of wolverines within a predator guild. Can. J. Zool. 86(9): 966–975. doi:10.1139/Z08-073.

van Dijk, J., Gustavsen, L., Mysterud, A., May, R., Flagstad, Ø., Brøseth, H., Andersen, R., Andersen, R., Steen, H., and Landa, A. 2008b. Diet shift of a facultative scavenger, the wolverine, following recolonization of wolves. J. Anim. Ecol. 77(6): 1183–1190. doi:10.1111/j.1365-2656.2008.01445.x. PMID:18657209.

Waits, L.P. 2004. Using noninvasive genetic sampling to detect and estimate abundance of rare wildlife species. *In* Sampling rare or elusive species. *Edited by* W.L. Thompson. Island Press, Washington, D.C. pp. 211–228.

Weaver, J.L., Paquet, P.C., and Ruggiero, L.F. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conserv. Biol. 10: 964–976. doi:10.1046/j.1523-1739.1996.10040964.x.

Wheatley, M., and Johnson, C. 2009. Factors limiting our understanding of ecological scale. Ecol. Complex. 6: 150–159. doi:10.1016/j.ecocom.2008.10.011.

Wheatley, M., Larsen, K.W., and Boutin, S. 2002. Does density reflect habitat quality for North American red squirrels during a spruce-cone failure? J. Mammal. 83: 716–727. doi:10.1644/1545-1542(2002)083<0716:DDRHQF>2.0.CO;2.

Whittington, J., St. Clair, C.C., and Mercer, G. 2005. Spatial responses of wolves to roads and trails in mountain valleys. Ecol. Appl. 15: 543–553. doi:10.1890/03-5317.

Wiens, J.A., Stenseth, N.C., Van Horne, B., and Ims, R.A. 1993. Ecological mechanisms and landscape ecology. Oikos, 66: 369–380. doi:10.2307/3544931.

Williams, B.K., Nichols, J.D., and Conroy, M.J. 2002. Analysis and management of animal populations. Academic Press, New York.

CERTIFIED MAIL

7017 0530 0000 4843 3049

Public Interest Defense Center
PO Box 7584
Missoula, MT 59807

Secretary, US Dept of Ag
1400 Independence Ave.
Washington D.C. 20250

USDA \ MRMD \
1/17/2020 8:27:49 AM
To perdue. Sonny
Agenc OES
Stop Co 3301
Locatio WHITTEN BUILDI
Room: 116A

70170530000048433049