

Guidelines for Winter Recreation near Wolverine Dens in Montane Western North America

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Abstract

Wolverine den in snowy areas with boulders or woody debris at or below tree line in montane western North America. They have naturally low reproductive rates, a fidelity to denning areas, and a sensitivity to human presence during denning. The goal was to synthesize existing ecological information for denning wolverine and identify risks from human presence in the categories of timing, distance, footprint, pattern of use, and frequency of use. The authors suggest commercial tenure holders and private users keep recreation in the low-risk category to minimize disturbance on denning females. Denning area surveys should be conducted prior to tenure application or renewals and dens can be identified by a concentration of tracks over more than three weeks from January 15 to May 15. Recreation should be restricted within a 5-km radius of confirmed dens during this window. Best practices include limiting the number of groups and concentrating movement on existing linear features as wolverine are sensitive to disturbance at a very low intensity of use and are at greatest risk when disturbances are dispersed and unpredictable.

Keywords: wolverine dens, winter habitat, denning

Introduction

Human footprint

Throughout the world, wildlife habitat is changing rapidly due to extensive land use changes and rising consumption of natural resources (Díaz et al. 2019a). Human-caused landscape modification is the primary cause of worldwide decline in biodiversity (Díaz et al. 2019b). In addition to habitat impacts, referred to as human footprint, human presence is also perceived as a threat by many species (Frid & Dill 2002; Suraci et al. 2019). The effects of human footprint versus human presence on wildlife habitat are not easy to disentangle (Nickel et al. 2020). Most wildlife is subject to both forms of anthropogenic disturbances, which may have cumulative effects (Wilson et al. 2020).

Increasing numbers of people are spending time in otherwise intact and protected areas (Balmford et al. 2015) crucial for wildlife conservation, especially large carnivores (Ripple et al. 2014; Rich et al. 2017), including wolverine (Krebs et al. 2004; Heim et al. 2017;

Heinemeyer et al. 2019; Kortello et al. 2019; Mowat et al. 2020). Most recreational disturbances are sub-lethal, and their effects on wildlife range from positive to neutral to negative (Larson et al. 2016; Tablado & Jenni 2017; Heinemeyer et al. 2019; Wilson et al. 2020). Negative sub-lethal impacts of recreation on wildlife can include increased movement, changes in spatial or temporal habitat use, declines in abundance, occupancy, or density, physiological stress, or reduced reproduction (Larson et al. 2016). The strongest negative effects are expected if biological processes such as foraging or reproduction are interrupted (Arlettaz et al. 2015; Tablado & Jenni 2017).

No studies have been conducted on sub-lethal impacts of human disturbance, including from commercial and private winter recreation, on wolverine denning, because such studies would not be ethical due to the conservation status and low numbers of wolverine. However, numerous wolverine researchers have documented wolverine moving their den sites, seemingly in response to researchers approaching them, suggesting there is low tolerance to humans near these sites (Copeland 1996; Scrafford & Boyce 2015; Jokinen et al. 2019; Glass et al. 2022; Scrafford & Ray 2022).

Wolverine ecology

Wolverine (*Gulo gulo*) are a mesocarnivore found in Eurasia, North America, and Europe (Fisher et al. 2022). In British Columbia, wolverine (*Gulo gulo luscus*) are assessed as threatened; federally, they are assessed as special concern. Wolverine was recently listed as a threatened species under the US Endangered Species Act (NatureServe 2024). They are facultative scavengers and reside in habitats that support large-bodied predators and a diversity of prey (Fisher et al. 2022). In southern British Columbia and Alberta, wolverine populations are fragmented (Cegelski et al. 2006; Schwartz et al. 2009), densities are low at < five animals per 1000 km² (Mowat et al. 2020), and declines have been documented including in protected landscapes with high human use (Barrueto et al. 2022).

Reproductive rates are low for an animal of its size (Persson et al. 2006; Rauset et al. 2015), with an average annual birth rate of 0.6–0.7 offspring per adult female (Magoun 1985). While most adult females (≥ three years) mate every year, successful reproduction is dependent on body condition and winter food availability (Persson 2005).

Adult female wolverine defend large territories—approximately 340 km² in British Columbia (Mowat et al. 2020)—to meet energy demands for successful reproduction (Lindstedt et al. 1986). Wolverine reproductive output is associated with habitat quality (Rauset et al. 2015). However, wolverine are increasingly coming in contact with people (Fisher et al. 2022). Industry removes forests and creates roads (Price et al. 2021), providing a means to push recreation deeper into intact, non-protected habitat. Winter and spring outdoor recreation in the mountains includes backcountry skiing, heli-skiing, cat-skiing, and snowmobiling. These activities overlap with wolverine denning and can disturb them at critical moments in their lifecycle, as has been shown for other species (Tablado & Jenni 2017). Heinemeyer et al. (2019) found female habitat to be degraded on average by 14.1% +/-9.4% through an increasing recreation footprint.

Female wolverine exhibit territorial fidelity, and fidelity to denning areas within territories, across years and generations (Copeland 1996; May et al. 2012; Aronsson & Persson 2018; Jokinen et al. 2019; Scrafford & Ray 2022). Use of the same denning areas by successive unrelated breeding females emphasizes these denning areas' importance (Magoun & Copeland 1998; Aronsson & Persson 2018). In Scandinavia, most (86%) radio-marked female wolverine ($n = 122$) remained in existing home ranges annually; the six wolverine that abandoned territories were in good body condition and reproduced before

and after dispersal (Aronsson & Persson 2018). This suggests factors other than food, such as competition or disturbance, can cause territory abandonment.

Objectives

Wolverine maintain home ranges over many years, in some cases within landscapes supporting significant winter recreation, suggesting that they tolerate those activities at some level (Heinemeyer et al. 2019). However, given their inherently low reproductive rates, low apparent tolerance to human presence during denning, and habitat degradation due to recreation, best practices for recreation in wolverine habitat are needed that conserve denning habitat. The only available guidelines for commercial and private recreation that outline best practices around wolverine dens are for British Columbia (BC MOE 2006). The desired outcome concerning wolverine dens in areas used by winter recreation is “continued occupancy of denning habitats,” but no information is provided on how to identify or monitor this (BC MOE 2006). These gaps are directly targeted by the suggested guidelines in this article.

Wolverine have different habitat requirements in different ecosystems; this article specifies ecology for montane ecosystems where wolverine den in deep, persistent snowpacks and where commercial winter recreation is widespread: in British Columbia, Alberta, Montana, Idaho, Wyoming, Washington, and Oregon. As limited information exists on wolverine denning behaviour in the montane ecosystem, this article references den behaviour from across their global range.

Due to wolverine’s conservation status in montane North America (NatureServe 2024), guideline updates must apply the precautionary principle, which ensures that an activity posing a substantial or irreversible threat is prevented from occurring even when there is insufficient scientific evidence linking that particular activity to environmental damage (Cameron & Abouchar 1991; Myers 1993).

The following guidelines are intended for operational practices by commercial recreation and adventure tourism operators, the commercial recreation tenure application or renewal process, and the private recreational backcountry user. The risk assessments provided here are based on expert opinion and are focused on informing management of wolverine habitat in montane portions of British Columbia and Alberta. Specifically, the objectives were to:

- 1 Provide descriptions of wolverine and wolverine dens to help people recreating in wolverine habitat search for and recognize denning activity.
- 2 Provide expert opinion on risks to wolverine denning associated with timing, pattern, distance, footprint, and frequency of use and offer guidance to mitigate that risk for a suspected or identified den site or denning area.

Methods

Den sites were compiled from two studies in the Columbia Mountains using different methods. The first study was conducted from 1995 to 2003, north of Revelstoke BC and west of Golden, BC, where 17 reproductive dens from 8 radio-tagged females were identified (Krebs et al. 2007). Reproductive den sites were identified from winter aerial telemetry followed up by ground-based site visits post-denning. Site use was confirmed from telemetry, concentrations of tracks, photographs, and ground visits.

The second study was conducted south of Revelstoke BC in the Selkirk Mountains from 2019 to 2023. Reports of wolverine or tracks in southeast British Columbia during the denning season (mid-Feb to mid-May) were solicited. Reporters were asked to describe

the distance they were to the wolverine, and how the wolverine reacted. Observations were classified as confirmed if they included clear photos of wolverine or tracks. If the observations gave a thorough description that left little doubt as to the animals' identity, they were classified as convincing. All other observations were discarded.

Clusters of citizen sightings, areas of female winter habitat (Kortello et al. 2019), and previously identified denning areas were surveyed or monitored by unmanned aerial vehicle (UAV), remote cameras, and helicopter. For aerial surveys, researchers waited approximately 50 hours after snowfall to allow animals to leave trails. During helicopter surveys, four observers, including the pilot, searched for fresh tracks in the snow. Cameras with long lenses were used to confirm track identification and to avoid flying too close to den sites.

In the 2019–2023 study, researchers used the DJI Mavic Pro UAV equipped with a 1-mega-pixel Hasselblad camera to locate wolverine dens. Missions were flown approximately 2 km from staging areas, enabling access to difficult terrain and minimizing disturbance. Researchers used terrain-following software to fly the UAV a constant height of 100 m above the ground over a pre-programmed transect. To ensure complete coverage of the area, 20–30% overlap occurred between successive photos and amongst rows. The resultant images were reviewed manually to identify wolverine tracks. Both studies considered a concentration of tracks from mid-February to mid-May to be indicative of denning activity as the female must travel back and forth to the den to forage (May et al. 2012). Concentrations of tracks may also occur where wolverine catch large prey; however, this localized activity is limited to days, not weeks or months (Copeland 1996; Scrafford & Boyce 2018), and food remains or scat may be visible on the snow surface. GPS-collared wolverine foraging in the boreal forest of Alberta typically spent less than three days total at a large-prey event over three weeks (Scrafford & Boyce 2018). In the study area, large prey seldom overlaps denning habitat. Following protocols developed by wolverine researchers in Scandinavia, persistent concentrations of tracks occurring for > three weeks from February to May were used to distinguish wolverine denning areas (Brøseth & Andersen 2009; Rauset 2013).

A visit was conducted after June 1 to confirm den sites. These were confirmed by beds in the substrate, worn pathways to den sites, observation of kits, kit tracks or hair, large amounts of scat, prey remains, and/or repeated photographs of wolverine entering the den. Wolverine den sites can be distinguished from other wolverine excavations by multiple entrances and chambers, kit hair (May et al. 2012), and latrine chambers (Myrberget 1968; Magoun 1985), although lack of scat does not negate a den site (Jokinen et al. 2019). The size of the physical feature the den was located under, its aspect, the percent of slope, and elevation were recorded.

For locations identified without telemetry, researchers set up a wildlife camera (Reconyx Hyperfire Infrared Digital Game Camera Hc600) pointed at the den entrance after snowmelt to monitor activity in subsequent denning seasons. Cameras remained in position throughout the study period to passively monitor the den site and batteries and SD cards were replaced outside of the denning period. Starting in winter 2023, a run-pole and remote camera set up was placed approximately 3 km from dens to confirm reproductive status of females. A denning area includes a confirmed den or multiple dens and surrounding habitat used during the denning period (Scrafford & Ray 2022). These methods resulted in identifying four denning areas and seven confirmed dens.

Risk Assessment for recreation in known denning areas

Females may abandon dens and move kits to a different location due to human presence

at these sites (Myrberget 1968; Pulliainen 1968; Magoun & Copeland 1998; Scrafford & Boyce 2015; Jokinen et al. 2019; Glass et al. 2022; Scrafford & Ray 2022). Human disturbance is the main reason for den abandonment in other carnivores (Ciarniello et al. 2005; Reshamwala et al. 2021). Relocation of kits puts them at risk of predation (Persson et al. 2003). Females may provision denning areas prior to parturition (Inman et al. 2012); this strategy of stored food caches at or close to the den site shortens the time the female must be away from the den while the cubs are vulnerable to predation (May 2007).

Disturbance may cause a female to abandon a den and accept a lower quality location (Myrberget 1968) or degrade the quality of habitat available for rearing young (Heinemeyer et al. 2019). Resource abundance has been shown to impact reproductive output (Persson 2005; Rauset et al. 2015); therefore, denning areas that demonstrate annual reproduction may indicate excellent habitat quality. This article describes how to identify and survey for wolverine dens, evaluates the risks of den abandonment in terms of when and how recreation occurs, and provides guidelines to mitigate those risks.

Wolverine identification

Wolverine are the largest terrestrial member of the weasel family, similar in size to a medium-sized dog. Adult males and females weigh 13–18 kg and 7.5–12.5 kg, respectively (Magoun 1985; Copeland 1996). They give the impression of a bear cub with longer fur and a longer bushier tail (Figure 1). They are typically dark brown with a light lateral stripe that runs from shoulder to flank. Individuals can be identified by unique chest and throat patterns (Magoun et al. 2011; Figure 1). Hoary marmot (*Marmota caligata*), American marten (*Martes americana*), porcupine (*Erethizon dorsatum*), and fisher (*Pekania pennanti*) are commonly mistaken for wolverine. Wolverine have large paws and their tracks sometimes depict all five toes, as opposed to canine and feline tracks, which show four toes (Figure 2). Track size is approximately 8 x 8 cm; claws, a lumpy, chevron-shaped interdigital pad, and a solid metacarpal print registering on the front foot are visible in some substrates (Figure 2). In deep or degraded snow, track pattern, stride length, and width



FIGURE 1. Wolverine, captured by remote camera at den entrance, showing the characteristic bushy tail, lateral stripe, and chest pattern. The den was used for three subsequent years, confirmed by UAV flights, track concentrations during denning, and remote camera visits outside of the denning period.

Photo credit: D. Hausleitner & A. Kortello

combined can be used to distinguish the species. Wolverine typically move in a diagonal three-pattern lope (one-two-one), or a double-track (two-by-two) bounding gait (Figure 3), but a direct register pattern is also used, although they do not use this pattern over great distances (Moskowitz 2010). The stride and straddle length of the three-lope pattern is 75–150 cm and 20–40 cm, respectively. The stride and straddle length of the double track is 30–100 cm and 15–20 cm, respectively. American marten, porcupine, and Canada lynx (*Lynx canadensis*) tracks are commonly mistaken for wolverine tracks (Figure 4). The size of the Canada lynx track is similar to a wolverine track, but they seldom show claw marks and they do not travel in a lope pattern (Moskowitz 2010; Figure 4a). Porcupine create a similar trench to wolverine, but porcupine walk pigeon-toed, have smaller feet, and do not lope or bound, and a zig-zag mound of snow can be seen in between the foot falls in some snow conditions (Figure 4b). American marten typically travels in a double or triple bounding lope similar to wolverine but track size (approximately 5 x 6.5 cm) and straddle width (6–12 cm) is smaller than that of wolverine (Moskowitz 2010; Figure 4c).

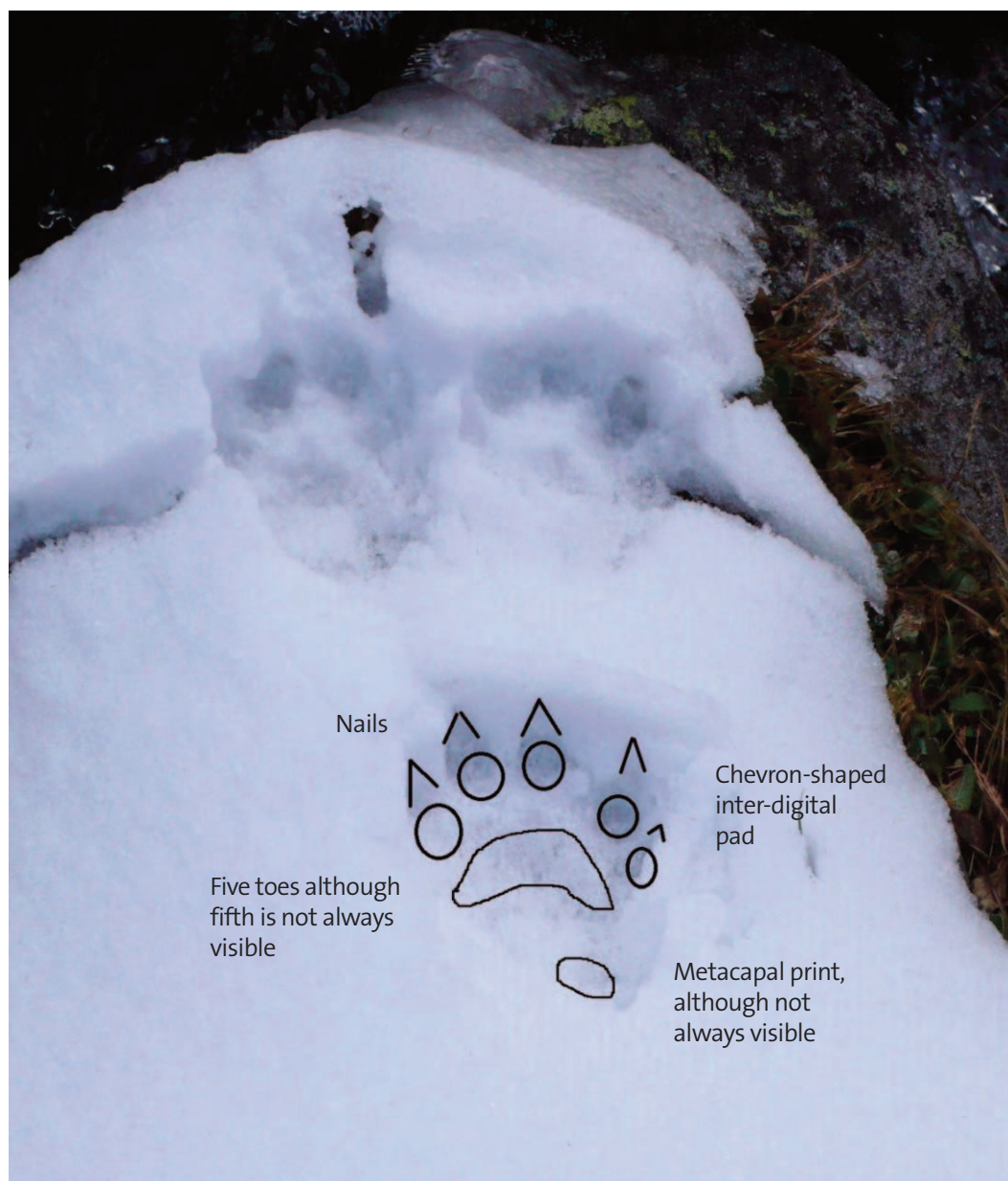


FIGURE 2. Wolverine tracks in snow depicting five toes, claws, chevron-shaped interdigital pad, and metacarpal print.

Photo credit: D. Hausleitner

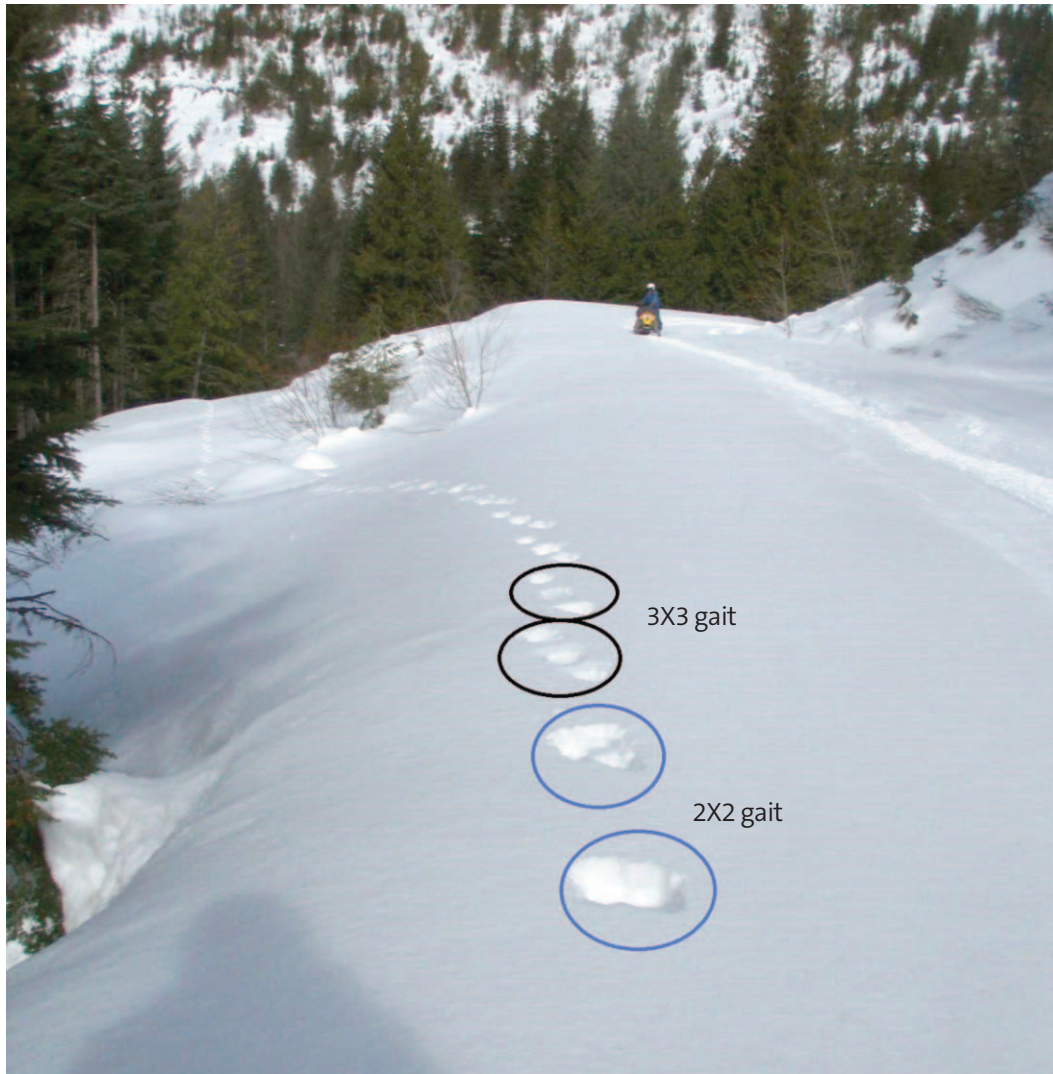


FIGURE 3. Wolverine double track bounding gait (left) and double track gait going into a three-pattern lope (right).

Photo credit: D. Hausleitner & A. Kortello



FIGURE 4. Track patterns of commonly confused species from left to right: a) Canada lynx, b) porcupine, c) American marten, and d) wolverine.

Photo credit: M. Barrueto & D. Hausleitner

Known den sites in montane western North America

A den site is a snow tunnel ending in a large boulder or woody debris used by a wolverine during the denning season. Dens provide kits with protection from weather and predators.

Wolverine occur at low densities and travel long distances making it difficult to identify denning areas; few have been described in montane western North America. Most dens were found using radiotelemetry (Magoun & Copeland 1998; Krebs et al. 2007) or GPS collars (Heinemeyer et al. 2019) or both (Yates et al. 2017).

Montane denning habitat

Wolverine occur in mountain complexes with a snowpack lasting into May, near tree line (Copeland et al. 2010; McKelvey et al. 2011; Magoun et al. 2017; Heinemeyer et al. 2019) with a low human footprint (Heim et al. 2017; Kortello et al. 2019; Barrueto et al. 2022). Female winter habitat models include forests, forest edges, talus slopes, and avalanche paths, which are important foraging and caching features (Krebs et al. 2007; Heinemeyer et al. 2019; Kortello et al. 2019).

Mean elevation of dens in the Columbia mountains and Glacier National Park (Yates et al. 2017) were 1697 m, SD = 209 m, $n = 24$, and 1890 m, $n = 14$, respectively. Dens are found in roadless drainages in upper elevation forests (Krebs & Lewis 2000) in boulder fields, below avalanche paths, or in cirque basins (Copeland 1996; Magoun & Copeland 1998). Denning terrain is rugged, but den sites occur on moderate slopes in both the Columbia mountains (0–22%; $n = 7$) and Glacier National Park (mean slope 16%, $n = 14$; Yates et al. 2017).

Two dens in Idaho described by Magoun and Copeland (1998) faced northerly and dens in the Selkirk mountains occurred on cold aspects (northwest, north, and northeast, $n = 7$), but north of Revelstoke, wolverine dens occurred on all aspects ($n = 17$).

Den entrances are 30–40 cm diameter excavations leading to complex tunnels dug into deep snow, often ending under a physical feature such as a bank, cliff, boulder, or wood (Copeland 1996; Magoun & Copeland 1998; Krebs & Lewis 2000, Magoun et al. 2017; Heinemeyer et al. 2019). Of the 24 dens



FIGURE 5. Wolverine den used in April 2022 in the Columbia Mountains under an 80-cm diameter windthrown Engelmann Spruce (*Picea engelmannii*) on a 5% slope with north aspect. Tracks, scat, beds, and hair were used to confirm this den. Photo taken September 20, 2022.

Photo credit: D.Hausleitner

described in the Columbia mountains, 33% ($n = 8$) occurred under woody debris (Figures 5 and 6) and 67% ($n = 16$) were associated with large boulders (Figure 7).



FIGURE 6. Wolverine den depicted in Figure 5, in the Columbia Mountains. Multiple wolverine tracks (orange dots demarcated) likely included juvenile tracks leading to the den. Photo was taken on April 7, 2022, from a helicopter.

Photo credit: A. Kortello



FIGURE 7. Wolverine den boulder in the Columbia Mountains with dimensions 6 m x 6 m x 2 m on a 14% slope with an easterly aspect. This boulder was used in March 2020 and April 2022.

Photo credit: D. Hausleitner

Den identification

Reproductive dens may be identified by multiple wolverine paths in the snow leading to a well-used entrance or under a boulder or woody debris, over a period of at least three weeks within the denning season, from early February to mid-May (Figures 8 & 9; Landa et al. 1998; May et al. 2012; Glass et al. 2022). Paths at denning areas may meander and travel in and out of boulders and there may be multiple paths of different ages radiating from a site of localized activity (Copeland 1996; May et al. 2012; Figure 10). Tracks that are likely *not* associated with a den are those travelling a straight line through an area (Figure 11) or tracks feeding on an animal carcass. The presence of prey remains on the snow surface near an entrance as well as duration of use may distinguish food caches, which are more common, from a reproductive den (Wright & Ernst 2004; Glass et al. 2022). While prey remains were not found at natal dens in Idaho ($n = 2$), they were present at maternal dens ($n = 16$; Copeland 1996). Additionally, wolverine may rest in burrows (Glass et al. 2022), but these are often associated with foraging events (Copeland 1996). In Idaho, most (73%, $n = 19$) resting sites were exposed and only 12% ($n = 3$) occurred in snow dens (Copeland 1996). Duration and degree of use and would distinguish these from den sites.



FIGURE 8. Wolverine modified Pika (*Ochotona princeps*) debris into a bed under the boulder depicted in Figure 7. This den had multiple entrances. UAV photos, tracks, scat, hair, and remote cameras were used to confirm this den. Photo taken July 26, 2020.
Photo credit: D. Hausleitner



FIGURE 9. Wolverine and two kits leaving the den depicted in Figure 7 and Figure 8 on April 13, 2022, after spending three days at the den. Den was monitored by a camera set up and removed outside of the denning period. The entrance can be seen towards the back of the photo.

Photo credit: D. Hausleitner

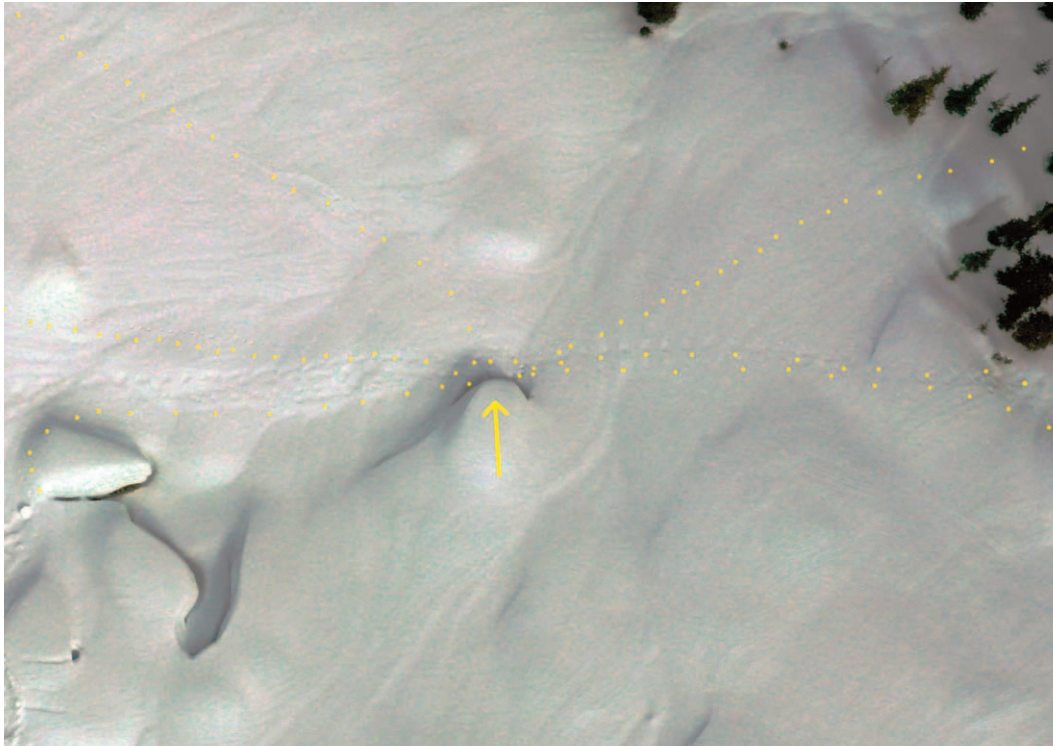


FIGURE 10. Wolverine paths, demarcated in yellow, radiating from a den 72-hours after snowfall. The den (arrow pointing at a snow-covered boulder) was at the toe of an 11% northeast talus slope under a boulder measuring 2 x 3 x 3 m. Photo taken April 30, 2019, by drone flown 100 m above ground. Den confirmed by UAV, scat, hair, and remote cameras.

Photo Credit: D. Greaves



FIGURE 11. Single line of wolverine tracks moving a great distance. Recommendations are not to follow the paths, take a photo (close up and track pattern) with a location, submit to www.wolverinewatch.org, and continue with normal activities.

Photo credit: A. Kortello

Timing

The denning season may be considered in two periods: den selection/parturition from January to mid-March and nursing/natal development from February through June (Pasitschniak-Arts & Larivière 1995; Inman et al. 2012). Den abandonment due to recreation may be most acute from February to April, when kits are immobile (Aronsson 2017; Heeres 2020) and up until May during natal development, when females and kits may use multiple dens (Aronsson et al. 2023).

Post weaning, late May until July, the family unit uses temporary rendezvous sites, where the female leaves kits while she forages (Copeland 1996; Inman et al. 2012). Juvenile wolverine are nearly full-grown and nutritionally independent from their mother by September (Inman et al. 2012). Post-weaned kits have higher survival rates than altricial kits due to increased mobility (Persson et al. 2003); and that increased mobility may enable them to avoid recreationists.

The risks of human presence near den sites are that female wolverine may shift den sites or indirectly lose access to habitat, thereby compromising reproductive output. High risk occurs during den selection, parturition, and natal development from January to mid-May. Moderate risk occurs May to July while the family is using rendezvous sites. Low risk occurs July through December when kits are mobile and nutritionally independent. The authors note that differences in timing may occur from north to south in the species' range.

Protective distance around den sites

The rationale for establishing a protective radius surrounding a den site is to prevent human disturbance at a den, preserve the denning area for foraging, and enable the female to shift den sites between and within years (Scrafford & Ray 2022).

Den sites in the Columbia Mountains were on average 17.0 km ($SD = 10.5$ km, $n = 24$) from major highways or all-season roads and 3.2 km ($SD = 2.5$ km, range: 0.28–10.3 km, $n = 24$) from forest service roads. While some of these forest service roads are used by winter recreationalists, others were too overgrown for access or occurred within parks where motorized use is prohibited. Eighty-eight percent (21/24) of den sites in the Columbia Mountains occurred < 5 km distance from the nearest forest-service road. In the boreal forest of Alberta and Ontario, where roads are not restricted by topography, den sites were 2.5–4.8 km ($n = 17$) from major highways and all-season roads, and approximately 1 km from smaller industrial roads (Scrafford & Ray 2022). Six dens described in boreal forest of Alberta were on average 6.1 km ($SD = 5.0$ km) from roads (Jokinen et al. 2019).

Reproduction output is tightly linked to food availability (Persson 2005), and females likely mitigate scarcity by provisioning denning areas with food caches (Inman et al. 2012). In the first three weeks post-parturition, females leave the dens for short travel periods, to forage or access food caches (May 2007; Aronsson et al. 2023). Only 20% of daily movements by 18 GPS-collared females in Sweden occurred > 1 km from the den site from mid-February to mid-March and mean distance travelled from den sites during the entire denning period was < 5 km (Aronsson et al. 2023). The average distance GPS-collared females moved from 17 known den site in the boreal forests of Ontario was < 4.5 km (Scrafford & Ray 2022). Provided that montane wolverine exhibits similar behaviors, a 5-km buffer around den sites should include adequate foraging and movement habitat. A 2-km buffer would likely also suffice during the early denning period when wolverine kits are immobile.

GPS-radio marked wolverine are shedding light on den shifting behaviours; in the Swedish study, the number of den sites changes and inter-den movements progressively

increased during the denning season with an average of 8.8 ± 8.5 dens per season per female over a ten-year period (Aronsson et al. 2023). As kits transition from nursing to food, multiple den sites may be required and the frequency of shifting and distances traveled increases (Heeres 2020; Aronsson et al. 2023). In the Columbia mountains, VHF radio-marked females generally used a single den per season (Krebs & Lewis 2000), but when den shifting was recorded (three of 14 female reproductive seasons), the distance moved was < 4 km. In Idaho and Alaska, 75% (3/4) and 30% (2/6) of VHF radio-marked females used multiple den sites per season and the distance between initial and subsequent dens was < 4 km (Magoun & Copeland 1998). As these females were tracked with VHF radio collars it is possible some den shifting was missed. In Alaska, Glass et al. (2022) reported distances of 0.3 km and 6 km from two initial dens. In Idaho, one den site was used by the same female for three consecutive years (Magoun & Copeland 1998) and two of seven dens were reused in the Columbia Mountains. Dens used by the same female in different years were an average of 5.3 km apart (range:1.6–7.3 km, $n = 5$) in the Columbia Mountains. Based on average den-shifting between sites and years, the authors believe that a 5-km buffer would be adequate to allow a female to move den sites undisturbed.

The authors suggest a 5-km radius buffer around den sites, based on wolverine den placement in relation to forest service roads, foraging, and movement behaviours in other studies and to allow for den shifting within and between seasons. A 5-km radius buffer may not be adequate in instances where recreation occurs throughout the female home-range, i.e., if the female lacks undisturbed refugia.

The potential risks of aircraft on wolverine have not been assessed, but den abandonment has been documented in grizzly bears (*Ursos arctos*) disturbed by heli-skiing or helicopters hovering over dens (Crupi et al. 2020). Where helicopters overlap bear denning, best practices recommend limiting flight duration and frequency and maintaining altitude > 500 m above ground (US Forest Service 2009). Of six public reports to www.wolverinewatch.org of wolverine from helicopters; in five instances, the wolverine acted afraid, and in one instance, it acted aggressively, lunging at the incoming helicopter, preventing it from landing. The nature of aerial disturbance to denning wolverine is unknown but likely depends on a combination of intensity of activity, timing, distance from the den site, and distance above the ground.

The risks of human presence near den sites are that female wolverine may shift den sites or that foraging and movement are compromised. The authors propose that high-risk activities include those occurring within 2 km of known dens. Moderate risk activities are those occurring 2–5 km from known dens and low-risk activities are those occurring > 5 km from known dens. Aircrafts can remain low risk by maintaining a height > 500 m above the ground within the buffer zones.

Frequency

Heinemeyer et al. (2019) captured the intensity of winter recreation use by recording tracks/100 m². Wolverine females displayed the greatest proportion of habitat degradation at low-recreation intensities (0–10 tracks/100 m²). Habitat degradation continued to increase with frequency of use (10–40 tracks/100 m²) but the rate of loss was more gradual. Similarly, the strongest decline in wolverine detection occurred with low human use (0–10 non-motorized groups per two-week period; Barrueto et al. 2022).

There is a low threshold for human frequency of use in wolverine habitat and these effects are expected to be amplified in areas used for denning. The risks of human presence near den sites are that female wolverine may shift den sites or lose access to foraging,

thereby compromising reproductive output. The authors suggest high-risk human frequency includes a frequency of > five groups/ two-week period. Moderate risk is two–five groups/two-week period and low risk is < two groups/two-week period.

Patterns of recreation movement

Linear features (roads or trails) concentrate recreation users and create spatially predictable travel, whereas recreation off linear features is dispersed and unpredictable. Wolverine exhibit the strongest avoidance to spatially unpredictable recreation, more so than motorized versus non-motorized recreation (Heinemeyer et al. 2019).

Citizen science reports of wolverine sightings were used to describe responses to non-motorized dispersed versus linear users. Eighty-one percent of wolverine ($n = 11$) sighted by dispersed users changed behaviour in response to human presence, whereas only 57% of wolverine ($n = 26$) sighted by those using linear features showed a behavioural change.

Recommendations regarding human activity and bear denning also suggest winter activity be predictable and restricted to linear features (Linnell et al. 2000). Remaining on pre-existing routes concentrates the recreational footprint; wolverine may select den locations based on predictable patterns.

The risks of human presence near den sites are that female wolverine may shift den sites and compromise reproductive output through direct disturbance or indirectly through habitat degradation. High risk activities include dispersed recreation within the denning area. Moderate risk activities include predictable recreation use on linear features.

Footprint

The larger the spatial extent of recreation, presumably, the greater the potential impact on reproductive success. Motorized users may pose a higher risk on wolverine than non-motorized users because they are able to cover larger areas of the winter landscape. In the western U.S., females showed the strongest avoidance to off-road motorized winter recreation as it was unpredictable and occurred frequently and over a larger footprint than non-motorized recreation in most wolverine home ranges (Heinemeyer et al. 2019).

To date, no research has been conducted that shows what level of disturbance across a female home range impacts reproductive success. Road densities impact wolverine presence (Krebs et al. 2007; Kortello et al. 2019) and density (Mowat et al. 2020) in montane ecosystems. Road densities also impact habitat selection and movement (Dawson et al. 2010; Scrafford et al. 2018) in the boreal forest and may act as a surrogate for footprint across a wolverine home range.

The probability of female wolverine occupancy in montane British Columbia during the reproductive period dropped by half (from 50% probability to 25%) when service road density increased from 0.1 km/km² to 0.5 km/km² (Kortello et al. 2019). Similarly, road densities greater than 0.44 km/km² increased the probability of displacement of wolverine from suitable habitat in the western United States (Rowland et al. 2003).

Home ranges of boreal female wolverine in Ontario were characterized by road densities less than 0.33 km/km² within a 50% Minimum Convex Polygon (Dawson et al. 2010). Alternatively, female wolverine in boreal Alberta tolerated low-volume service roads with a mean density of 0.58 km/km² within their winter ranges (Scrafford et al. 2018).

The spatial arrangement of the disturbance footprint in relationship to the den is probably important. Indeed, in Norway, females select dens further from infrastructure than available, and dens were at a minimum of 1.5 and 7.5 km from private and public

roads, respectively (May et al. 2012). In montane North America, forest service roads extend into subalpine denning areas and may be used as access for ski-touring, cat-skiing, or snowmobiling.

High road density may degrade the quality of the denning habitat. High risk is road densities of $> 0.5 \text{ km/km}^2$ within a denning area. Moderate risk is road density between 0.1 km and 0.5 km^2 and low risk is road density $< 0.1 \text{ km/km}^2$.

Guidelines

Wolverine are individuals and may respond differently to human presence. The precautionary principle has been applied to these recommendations. Both commercial and private recreationists should be aware of, interpret and report wolverine activity during the denning period. An attempt should be made to remain in the “low” risk categories at confirmed den sites.

Operations of commercial recreation and adventure tourism

- Single path/sighting: recommendations are to not follow the path, take a photo (close up and track pattern) with a location, submit to www.wolverinewatch.org, and continue with normal activities (Figure 10).
- If a concentration of wolverine paths is found during the denning season without evidence of a carcass, it should be presumed to indicate a den site and recreation within 2 km of the site should cease until the den location is confirmed on a second visit. Aircrafts should remain $> 500 \text{ m}$ above the ground within this buffer zone. The authors perceive this 2-km buffer to be at moderate risk for wolverine disturbance.
- A repeat visit should be done three-four weeks later aerially via UAV or helicopter survey versus an on-the-ground survey. Aerial surveys have potential for disturbance, and UAVs are less disruptive and function better than helicopter surveys in forested habitat. To maintain a distance from the ground, use cameras and binoculars in helicopter surveys. If a good line of site is available, a repeat observation can be made with binoculars from a distance. Because observer presence can result in den shifting, or because wolverine may naturally shift den sites, the second survey should include the original den site and at minimum a 5-km radius around the original area if conducted before mid-April. After that time, distances between den sites may increase (Aronsson et al. 2023). If a repeat visit confirms activity, then a 5-km radius should be used and aircrafts should maintain a height $> 500 \text{ m}$ above the ground within the buffer zone. The authors perceive this 5-km buffer to be at low risk for wolverine disturbance.
- If a small lodging recreation infrastructure exists within the 2 or 5 km suggested boundaries, with recreation occurring during den establishment, then reduce group frequency to \leq two groups/two weeks and move as far from the denning site as possible and in a predictable fashion, using the same up track, skiing the same descents for the denning season January 15 to May 15.
- Where a confirmed den exists $< 5 \text{ km}$ from a large recreation infrastructure (large multi-helicopter/snowcat lodge with $> \text{five groups/two-week period}$), an avoidance plan should be created that meets the intent of the buffer protection, addresses access, and restricts use within the 5-km buffer for the denning season (January 15 to May 15).
- A den site may be used in consecutive years or reproduction may skip a year. If possible, move recreation activities from the den site completely. If it is not possible to move recreation activities out of the area (i.e., denning occurs in proximity to an established lodge), re-survey a site aerially in late February prior to recreation activities to determine re-use.
- Report potential and confirmed den site with coordinates and photos to the regional biologist and www.wolverinewatch.org.

Tenure application/renewal for commercial tenure holders/ land managers

- Tenure applicants, tenure holders, or land managers should search for denning areas prior to the application process or before renewal with repeat helicopter surveys more than three weeks apart with trained wildlife professionals in denning habitat. Flights should be conducted 48–72 hours after the last snowfall and when females increase movements in mid-March to late April (Aronsson et al. 2023). If conditions are good for snow tracking, late April and early May is best to detect female and kit tracks (Aronsson et al. 2023). Wolverine dens are difficult to find, especially in dense canopy cover. Ideally, a search should be repeated over a minimum of a two-year period as wolverine do not typically reproduce annually.
- If a den site is suspected, the second survey should include the original den site and a minimum 5 km radius from the den if conducted before mid-April. After that time distances between den sites may increase (Aronsson et al. 2023). If a repeat visit confirms denning, then a 5-km protective radius should be applied to the den site(s). Aerial traffic should maintain a distance of 500 m above the ground in this buffer. The authors perceive this 5-km buffer to be at low risk for wolverine disturbance.
- Setting up cameras at suspected den sites can be used to further categorize a wolverine excavation as a den or a cache (Scrafford & Ray 2022), as these can be difficult to distinguish. The authors suggest setting up cameras outside of the denning period (June–January) as researcher visits near den sites has resulted in abandonment. While the cameras will miss the current year's reproduction, the den site can be further inspected for evidence of use in the summer including a latrine, bedding areas, and cub hair (May et al. 2012).
- Alternative methods to confirm same-season reproduction would be to set up a run pole and remote camera (Magoun et al. 2011) in the denning area but a sufficient distance (> 2 km) from the suspected den site, to document productivity (Scrafford & Ray 2022). Additionally, some success has occurred using scat to assess reproduction status of wolverine, provided scat is collected between December and February (Bateman et al. 2023). While radio-telemetry may be the most effective way to discover new den sites (Scrafford & Ray 2022), it requires animal capture, long-term monitoring effort, and expense that may not be realistic for the tenure application process.
- Maintain road densities < 0.1 km/km² within 5 km of known den sites to remain in a low-risk category.

Private recreation users

- Single path/sighting: recommendations are to not follow the paths, take a photo (close up and track pattern) with a location, submit to www.wolverinewatch.org, and continue with normal activities (Figure 10).
- Multiple paths/networks of paths, not associated with a prey-event observed once during denning period: assume this is a denning area and avoid the basin/drainage around the site until mid-May. Report the possible den with coordinates and photos of tracks to the regional biologist and www.wolverinewatch.org.
- Avoid the basin/drainage until mid-May if a wolverine emerges from or disappears into a snow hole.

Conclusion

These guidelines have been compiled based on a wide body of research, known wolverine responses to human presence and expert opinion, they should be adapted as new data becomes available. Risk factors for denning disturbance likely have interacting and compounding effects. For example, a single snowmobile on a trail within 5 km of a den site in

February may not pose as high a risk as multiple groups of ski-tourers dispersed on the landscape within 5 km of a den site.

Researchers do not fully understand how wolverine reproductive output is impacted by recreation; tenure holders that have shown repeated evidence of wolverine reproduction should be lauded for their approach. To identify and manage risks for conserving wolverine, building competence in the recreation sector is required. Careful documentation of user group numbers and their travel patterns together with documentation of wolverine reproductive success will help to define disturbance tolerance ranges and fine-tune guidelines.

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