
Effects of Helicopter Skiing on Mountain Goats and Woodland Caribou in British Columbia

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ABSTRACT

*Helicopter skiing is a popular adventure tourism activity that occurs within the range of mountain goats (*Oreamnos americanus*) and/or woodland caribou (*Rangifer tarandus caribou*) in British Columbia and, to a lesser extent in adjacent jurisdictions. Both are species of concern, with known or suspected population declines occurring in substantial portions of their respective ranges. Whether helicopter skiing is contributing to these declines is of interest to governments and the sector. Here, I review available literature in the context of a conceptual model of potential impacts, to assess available evidence for adverse effects. Most studies have assessed the short-term behavioural responses of mountain goats and woodland caribou to approaches by helicopters and skiers, and a clear dose-response relationship has been demonstrated. Studies of GPS-collared mountain goats and woodland caribou have not correlated displacement from preferred habitats with helicopter skiing activities, although one study presented evidence that backcountry ski touring displaced caribou. Effects on survival and/or reproduction have not been studied. Additional studies of faecal cortisol concentrations may provide additional insight, if correlated with other responses. Understanding the demographic consequences of helicopter skiing is important for management of the sector but will likely be challenging to estimate. Setting socially acceptable levels of impacts from this and other sectors will be important to maintain or restore self-sustaining populations of mountain goats and woodland caribou.*

Keywords: *mountain goats, *Oreamnos americanus*, woodland caribou, *Rangifer tarandus caribou*, helicopter skiing, British Columbia*

Introduction

Mountain goats (*Oreamnos americanus*) and woodland caribou (*Rangifer tarandus caribou*) are species of intense management interest in British Columbia (BC). The conservation status of mountain goats was up-listed from *Yellow* to *Blue* by the BC Conservation Data Centre (<https://a100.gov.bc.ca/pub/eswp/>) in 2015 to reflect concerns about declining populations in some regions of the Province. The Southern mountain population of

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woodland caribou is federally listed as *Threatened* and a recovery strategy was posted in 2014 (Environment Canada, 2014).

Mountain goat and woodland caribou habitat is protected within parks and protected areas and in legally designated Ungulate Winter Ranges (UWRs) and Wildlife Habitat Areas (WHAs). Adventure tourism activities, including helicopter skiing, are allowed under permit in some parks, UWRs, and WHAs. Concerns about potential impacts led to the development of *Tourism Wildlife Guidelines* (<https://www.env.gov.bc.ca/wld/twg/index.html>) to promote best practices by adventure tourism operators when conducting activities near wildlife and their habitats.

Debate regarding best practices has continued because populations of both mountain goats and woodland caribou are known or suspected to be declining in many parts of BC. Whether helicopter skiing is contributing to this decline and how its impacts can be mitigated are important questions for both governments and the sector.

I conducted a literature review of the impacts of helicopter skiing activities on mountain goats and woodland caribou to determine the state of evidence for impacts of the sector's activities on these species. The purpose of the review was to gauge empirical support for a conceptual model of the effects of stimuli associated with helicopter skiing activities on conservation outcomes for mountain goats and woodland caribou (Figure 1). Stimuli can elicit physiological responses that might affect reproductive performance, either directly or indirectly via changes in behaviour. Behavioural changes might also cause animals to be displaced from their preferred habitats, which could in turn cause lower survival and/or reproduction.

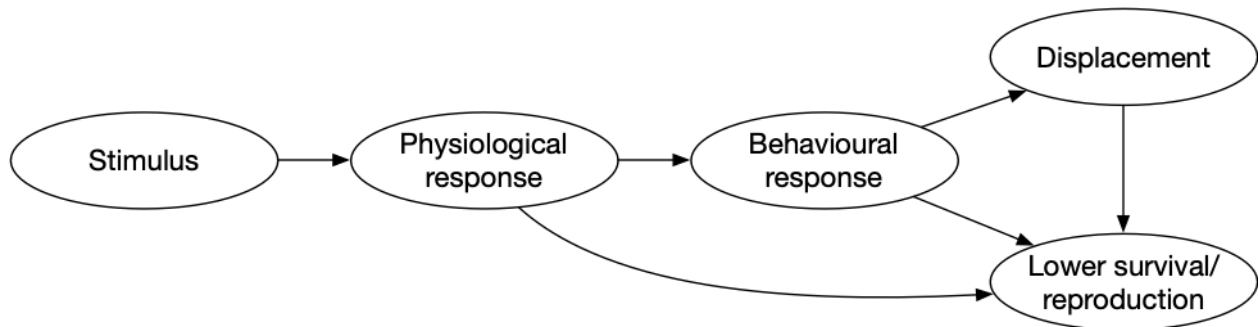


Figure 1. Conceptual model of mountain goat and woodland caribou responses to stimuli associated with helicopter skiing activity.

Methods

I structured the literature review using guidance from Hansen et al. (2022) on conducting meta-analyses, using the following steps:

Research Question

The research question investigated by this literature review was: how do mountain goats or woodland caribou respond to helicopters and/or skiers?

Literature Search

I conducted my literature search using Google Scholar and the search terms:

1. "Mountain goats" AND helicopters AND response
2. "Mountain goats" AND ski AND response
3. "Caribou" AND helicopters AND response
4. "Caribou" AND ski AND response

Study Inclusion Criteria

Only peer-reviewed journal articles and theses that presented original research related to either mountain goats or woodland caribou were included. Review articles or papers that analyzed data from other studies were omitted, as were studies that used helicopters for surveying animals but measured responses to something else.

Studies that reported the response of animals to ski areas and resorts, rather than skiers, were also omitted.

Each Google Scholar search was concluded when the first page that listed no study that met the inclusion criteria was encountered.

Effect Size Measures

I evaluated the responses of mountain goats and woodland caribou with respect to: 1) evidence of behavioural responses; 2) physiological responses; 3) changes in movements; 4) changes in habitat use (i.e., displacement); or 5) changes in demography (i.e., survival and/or reproduction).

While several studies categorized responses of animals at different helicopter or skier approach distances, response and distance classes varied among studies, complicating comparisons. For this review I re-classified response categories from each study to a low-moderate-high scale to allow pooling and comparison of results (Table 1).

Table 1. Reclassified behavioural categories for the review of responses of mountain goats and woodland caribou to helicopters skiing.

Study	Low	Moderate	High
Côté (1996) and Côté et al., (2013)	No/light (alert for <2 min or moved <10 m)	Moderate (moved 10-100 m or alert >2 and <10 min)	Great/strong (walked or ran >100 m or were alert for >10 minutes)
Goldstein et al. (2005)	Maintenance	Alert, Vigilant	Fleeing
Foster and Rahs (1983)	Maintenance	Alerted	Moderate flight, Severe flight
Huebel (2012)	No significant change in movement	Change from resting to standing, standing to walking	Standing and feeding to running away
Wilson and Wilmshurst (2019)	No reaction, unconcerned, curious	Concerned	Alarmed, very alarmed

Stimuli were noted as caused by either helicopters or skiing, or both if the study did not distinguish between the two. Because all but one study (Wilson and Wilmshurst, 2019) used a single type of helicopter, or used unspecified helicopters, it was not possible to compare effects of different machines.

Analysis

A quantitative meta-analysis of impacts was not possible because source data from studies was not available. Instead, support for each causal relationship in the conceptual model (Figure 1) was assessed by whether the relationship had been studied and whether there was evidence of a dose-response relationship.

Results

Responses of Mountain Goats

The literature search for behavioural responses to helicopters by mountain goats returned four studies that met the criteria. These included two papers based on long-term behavioural monitoring of mountain goats at Caw Ridge that recorded responses during opportunistic approaches by helicopters (Côté, 1996; Côté et al., 2013). One experimental study recorded behavioural responses of goats to helicopters flown on approaches at four study areas in Alaska (Goldstein et al., 2005), and one other study observed responses of goats to helicopters as part of a broader study of impacts of mining activities (Foster and Rahs, 1983).

Côté (1996) provided a table of responses by distance categories and reported that *low* responses occurred only at distances >1500 m and that approaches by helicopters of <500 m resulted in *high* reactions in 85% of observations (n = 20). Goldstein et al. (2005) presented modelled responses illustrating that the distance at which 90% of observations resulted in a *low* response was 991-1730 m, depending on study area. In response to helicopters at <500 m, the probability of a *high* response varied 0-40%, depending on the study area and exact distance.

All studies provided summaries of responses, regardless of distances (Table 2), suggesting that *low* is the most common response of mountain goats to helicopters, regardless of distance.

Table 2. Summary of observed responses of mountain goats to helicopters at all distances.

Study	Behavioural response			Total
	Low	Moderate	High	
Côté (1996)	34	21	26	81
Côté et al. (2013)	51	37	46	134
Foster and Rahs (1983)	25	43	72	140
Goldstein et al. (2005)	227	88	32	347
Total observations	48%	27%	25%	702

One study examined changes in movements and habitat use of mountain goats in response to helicopter skiing activity, using GPS telemetry and flight data from a tenure in northwestern BC (Cadsand, 2012). Seasonal movements and seasonal home range size did not change with increasing exposure to helicopters at distances <2000 m, and goats were generally not displaced, despite evidence that movements were affected for 48 h post-exposure. Mountain goats did not avoid areas frequented by helicopters, although there was some evidence of an increase in use of escape terrain in response to activity.

No studies were found that examined the physiological or demographic effects on mountain goats of helicopter encounters, nor studies of the specific effects of skiers on mountain goats.

Responses of Woodland Caribou

The literature search returned three studies that specifically looked at behavioural responses of mountain caribou to encounters with helicopters. In one study, 72% of approaches <500 m resulted in a *low* response and 14% in a *high* response, among 252 observations (Wilson and Wilmshurst, 2019). Huebel (2012) recorded caribou behavioural responses to helicopters and skiers and found no evidence that the frequency of *high* responses

increased in areas with more helicopter skiing activity. She did not report responses by distance categories. The frequency of different behavioural responses was similar in both studies (Table 3). Both Huebel (2012) and Wilson and Wilmshurst (2019) analyzed observation data collected by helicopter skiing operators.

Table 3. Summary of observations of responses of woodland caribou to helicopters at all distances.

Study	Behavioural response			Total
	Low	Moderate	High	
Huebel (2012)	28	2	0	30
Wilson and Wilmshurst (2019)	224	20	8	252
Total observations	89%	8%	3%	282

Harrington and Veitch (1991) recorded responses during two helicopter approaches as part of a larger study of the effect of military jet overflights on woodland caribou in Labrador, Canada. They recorded caribou moving a median of 19 seconds for a median distance of 85 m following a very close encounter with a helicopter (30 m altitude, ≤ 50 to the side), and for the same duration a median distance of 31 m following a helicopter encounter of >50 altitude and >50 m to the side.

Freeman (2008) measured faecal cortisol concentration to assess stress responses among caribou following close encounters by helicopters during surveys and in areas with and without documented helicopter skiing activity. Following two controlled approaches to groups of caribou that involved flying <500 m for several minutes, cortisol concentration results were inconsistent, with one group showing an increase post-encounter and another showing a decline. In the area-based analysis, pellets collected within a helicopter skiing tenure had significantly higher cortisol concentrations than pellets collected in a park where the activity was not permitted.

Huebel (2012) studied changes in movements and habitat use in relation to helicopter skiing activity and in an adjacent park that served as a control. Caribou were not found near ski runs significantly less than expected and were not displaced by increasing levels of activity. Nor were movement rates of caribou higher within the helicopter skiing tenure than in the park.

Several studies have focused on the effects of skiing on woodland caribou. Duchesne et al. (2000) studied changes in time budgets of caribou before and after close approaches (20 m) by naturalist-led groups on cross-country skis and snowshoes in a Québec park. The primary effect of visits was to increase time spent vigilant and to decrease foraging, but also to decrease resting and increase standing and walking.

Wilson and Wilmshurst (2019) analyzed behavioural responses of caribou to encounters with backcountry downhill skiers in tenures in BC. Among 61 skiing encounters, 41% of approaches <500 m resulted in a *low* response and 34% in a *high* response.

Lesmerises et al. (2018) examined effects on movements and habitat use of woodland caribou in response to an index of ski touring activity near a backcountry cabin in a Québec park, as measured by GPS collar data. They found evidence of displacement to lower elevations and faster movement rates for approximately 3 days after the onset of skiing activity.

No studies were found that examined the demographic consequences of helicopter encounters with woodland caribou and no studies that examined the physiological or demographic consequences for caribou of encounters with skiers.

Discussion

The effect of helicopter skiing activity on mountain goats and woodland caribou has been the focus of relatively little peer-reviewed literature. In part this is because the activity is relatively restricted geographically, co-occurring with goats and caribou primarily in BC and in small areas of Alaska and Yukon.

Reactions to helicopters and skiing by these species have also been observed in other contexts that bear some similarities to helicopter skiing, but with some significant differences. Most importantly, helicopter skiing operators are required to avoid interactions with wildlife while flying and skiing, temporarily close areas following sightings, and to maintain records of sightings and their operational responses. In contrast, most of the studies reviewed involved passive flying and skiing activities that were conducted without regard for potential interactions with wildlife (e.g., Côté, 1996; Côté et al., 2013; Lesmerises et al., 2018), or involved deliberate close approaches (e.g., Duchesne et al., 2000; Freeman, 2008; Goldstein et al., 2005; Harrington and Veitch, 1991). Differences among studies in encounter frequencies (especially close encounters) and wildlife responses could reflect the effects of mitigations that apply specifically to helicopter skiing operators.

While results from studies based on data from the helicopter skiing sector reflect outcomes that include attempts to mitigate impacts, they could also be subject to bias and/or under-reporting (Wilson and Wilmshurst, 2019). Data in these studies were collected by pilots and guides while they were engaged in helicopter skiing activities, compared to other studies that used dedicated and independent observers. Based on an analysis of flight paths in relation to GPS-collared caribou, Huebel (2012) found that guides and pilots detected only 40% of encounters <500 m from caribou.

In relation to the conceptual model (Figure 1), the literature review identified only one study that measured physiological responses to both known and assumed helicopter encounters, with ambivalent results (Freeman, 2008). The extent to which cortisol and observed behaviour are correlated has not been studied in mountain goats or woodland caribou, and studies in other systems do not suggest a close association (e.g., Beerda et al., 1998; Ottenheimer Carrier et al., 2013; Schmid et al., 2001). Dulude-de Broin et al. (2019) linked faecal cortisol levels to lower reproduction by mountain goat females in a study focused on predation pressure. This is the only study to date that has linked cortisol concentrations to demographic consequences in either species. A challenge in these studies is that the experience of animals before their pellets are collected is generally unknown and cortisol responses are non-specific. Freeman (2008) could only assume that the presence versus absence of helicopter skiing activity was responsible for observed differences in faecal cortisol levels.

Most of the studies reviewed measured the behavioural response of either mountain goats or woodland caribou to helicopter and/or skiing stimuli. General conclusions regarding the dose-response relationship observed among studies is challenging because of variation in study design. Some studies used encounter distance as a measure of the intensity of stimuli (e.g., Côté, 1996; Côté et al., 2013; Goldstein et al., 2005; Wilson and Wilmshurst, 2019), or used a binary presence-absence variable (e.g., Duchesne et al., 2000), while others inferred intensity based on geographic zoning (e.g., Freeman, 2008; Huebel, 2012; Lesmerises et al., 2018). While I was unable to assess the independent effect of different types of helicopters, Wilson and Wilmshurst (2019) found a small, independent helicopter effect, with “heavy” machines generating a stronger behavioural response by caribou than “light” machines.

Generalizing where possible suggests that the most common response to encounters with helicopters and skiing were minor (i.e., *low* as classified in Table 1) but there was a clear dose-response relationship with the probability of a *high* response occurring at closer encounter distances. In addition, skiers appeared to elicit stronger responses than helicopters (Wilson and Wilmshurst, 2019). Côté et al. (2013) found that mountain goats did not habituate to helicopter activity, with animals responding similarly over many years of study.

No studies correlated behaviour changes by animals to displacement, although displacement was studied in relation to helicopter skiing activities in both mountain goats (Cadsand, 2012) and woodland caribou (Huebel,

2012). In neither study was displacement detected in response to activities, although there was evidence of increased post-encounter movements among some mountain goats. Huebel (2012) reported movements by woodland caribou more generally and found that daily movements did not differ between the heliskiing tenure and the control area (park). Unguided backcountry ski touring was found to increase movements of caribou and displace them to lower elevations (Duchesne et al., 2000).

No studies have assessed the demographic consequences of helicopter skiing activity on mountain goats or woodland caribou. There has been speculation that displacement of caribou from preferred habitat may pose risks by exposing animals to more dangerous terrain (i.e., higher avalanche risk), deeper snow that could increase energy expenditure, reduce access to forage, or expose animals to higher risk of predation (Seip et al., 2007). In contrast, mountain goats when threatened tend to retreat to the relative safety of escape terrain, which might not be associated with all the same risks, but is associated with less forage (Hamel and Côté, 2007).

Because studies have yet to test the link between helicopter skiing activity and demographic decline, the consequences of responses documented to date on the sustainability of mountain goat or woodland caribou populations is unknown and can be inferred only if behavioural responses are assumed to lead to demographic consequences. Current evidence suggests that if behaviour is linked to demography, it is unlikely to be through the consequences of displacement, as studies of both mountain goats and mountain caribou have failed to detect evidence of displacement resulting from helicopter skiing activity.

Whether observed responses of these species to helicopter skiing is socially acceptable depends on the objective. If the objective is to prevent any changes in behaviour, then current evidence suggests that this is likely unachievable where helicopter skiing is permitted because chance encounters are unavoidable. An objective to prevent displacement may be achievable, at least where operators have implemented mitigations to minimize interactions with wildlife. If the objective is to prevent demographic decline, then current research provides no specific guidance.

Management Recommendations

The impact of helicopter skiing activities on mountain goat and woodland caribou demography remains unstudied but is important in order to understand whether the behavioural responses observed in several studies are likely to be consequential for the sustainability of populations. Such research is challenging because experimental treatments are largely infeasible, and impacts need to be inferred from observational evidence. Helicopter skiing varies in intensity at different spatial and temporal scales on land bases subject to a variety of different stressors and baseline ecological circumstances. As a result, the impact will need to be estimated by conditioning on the set of relevant factors that allows isolations of the helicopter skiing effect. This might be challenging where data are incomplete and/or if the effect size is small.

While studies based on industry provided data presented outcomes where operational practices attempted to mitigate negative impacts on mountain goats and woodland caribou (Huebel, 2012; Wilson and Wilmshurst, 2019), most studies reported unmitigated impacts of either general helicopter (e.g., Côté, 1996; Côté et al., 2013) or skiing (e.g., Lesmerises et al., 2018) activity. Further research is required to estimate the extent to which operating practices can be effective in mitigating impacts. Currently, only the helicopter skiing sector has implemented specific guidelines, but mountain goats and woodland caribou would likely benefit further from having all helicopter and ground-based activities follow similar practices. While there are likely limited opportunities to mitigate the behavioural dose-response relationship observed in studies of mitigated and unmitigated activities, practices focused on reducing the probability of encounters or re-encounters could be effective.

The helicopter skiing sector uses a variety of aircraft that differ considerably in size and noise characteristics. Whether these characteristics generate significantly different responses in wildlife requires additional study, and could provide another opportunity to mitigate impacts, particularly as technologies evolve.

Improving technologies might also provide opportunities for operators to improve their situational awareness and avoid chance encounters with wildlife. GPS-collared animals are easily avoided as near real-time location data are transmitted; however, capture and collaring is invasive and expensive, may sensitize wildlife to helicopters, and collars are rarely deployed on more than a small proportion of a population. Other, non-invasive technologies such as forward-looking infrared radar are evolving quickly and are being used to mitigate impacts on wildlife in other systems (e.g., Smith et al., 2020).

Avoidance of human-related activity by wildlife is widespread (Naidoo and Burton, 2020) and likely unavoidable where such activity is permitted. Setting socially acceptable limits on impacts of all activities, and employing practicable and effective mitigations, is required for wildlife to be sustainable outside protected areas.

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Declarations

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