A RISK-BASED APPROACH TO ASSESSING AND MANAGING DISTURBANCE EFFECTS OF HELICOPTER-LOGGING ON MOUNTAIN GOATS IN COASTAL BRITISH COLUMBIA

Steven F. Wilson[1], EcoLogic Research, 406 Hemlock Ave., Gabriola Island, BC V0R 1X1, Canada

Steve Gordon, British Columbia Ministry of Forests, Lands and Natural Resource Operations, Nanaimo, BC V9T 6J9, Canada

Abstract: Helicopter-logging activity can affect the behaviour of mountain goats and displace them from preferred habitat; however, recommended separation distances between mountain goats and helicopters have varied between 500 m and 2000 m. We used a risk-based approach to investigate the management implications of different separation distances in the context of helicopter-logging operations on the mainland coast of British Columbia (BC). We used results from available studies and the opinion of experienced biologists to develop a risk model that related helicopter-logging to effects on mountain goats. The model indicated that different separation distances could result in similar risks to mountain goats, depending on season and snow depth. Benchmarking the risks against BC's general approach to population management of mountain goats allowed us to provide more objective recommendations for helicopter-logging activity compared to previous recommendations.

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Key words: mountain goats, British Columbia, helicopter-logging, behaviour, modelling.

Mountain goats (*Oreamnos americanus*) are relatively common inhabitants of British Columbia's (BC) most rugged mountain habitats. Although populations in BC are considered secure, the Province has a global responsibility for their conservation because >50% of the world's mountain goats live in BC (Shackleton 1999).

Helicopter activity can alter mountain goat behaviour and displace them from habitat (Côté 1996, Harrison 1999, Gordon and Wilson 2004, Goldstein et al. 2005) but using helicopters to yard felled trees from otherwise inaccessible terrain (hereafter "helicopter-logging") is an economically important component of the forest industry in coastal BC. We used results from available studies and the opinion of experienced biologists to develop a risk model that related helicopter-logging to effects on mountain goats. Model results were used to develop legal requirements for helicopter-logging activity in a coastal timber supply area.

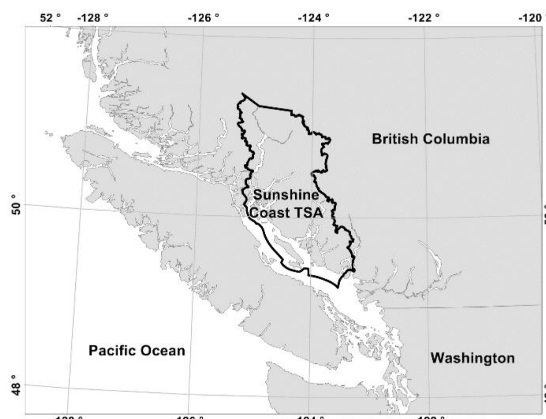

Fig. 1. Study area was the Sunshine Coast Timber Supply Area (TSA) in coastal British Columbia.

STUDY AREA

The risk model was developed specifically for the Sunshine Coast Timber Supply Area (TSA) of southwestern BC (Fig. 1). The TSA covered 19,359 km^2 of lowland coastal temperate rainforest rising to subalpine and alpine meadows, talus slopes, rock outcrops and peaks of >2000 m.

[1] Email: steven.wilson@ecologicresearch.ca

Snow was infrequent at sea level but typically reached depths of several metres at higher elevations. Deep snow between December and March restricted mountain goats to areas under dense tree canopies that intercept snow, or to snow-shedding escape terrain. Mountain goats can use winter ranges as low as sea level during severe winter conditions (Taylor et al. 2006).

METHODS

The risk model we developed was designed to meet the following objective: to maintain the distribution and abundance of mountain goats in winter range habitats in the project area. We assumed that mountain goats select optimal habitat to meet their life requisites and that displacement from preferred habitat could result in lower fitness due to:

1. increased likelihood of accidents (e.g., falls, avalanches);
2. higher risk of predation from being displaced from escape terrain;
3. poorer body condition caused by expending energy to flee in deep snow or hazardous terrain; and/or,
4. further nutritional deprivation from subsisting in sub-optimal winter habitats with fewer available forage resources and/or poorer thermal conditions.

Research has focused on the short-term behavioural responses of mountain goats to helicopter activities but fitness consequences remain largely unstudied (Wilson and Shackleton 2001). As a result, we used the opinion of local experts and their interpretation of relevant scientific and management literature to develop an adaptive management hypothesis that could be used to inform current management and provide a rationale for future monitoring and refinement of management approaches.

Behavioural changes by mountain goats in response to helicopter activities, and their habitat use and fitness consequences, are probabilistic (i.e., the outcome of a single event cannot be reliably predicted, but different outcomes occur with predicable frequencies when many events are observed). Consequently, we modelled the system as a Bayesian Belief Network (BBN), which uses probabilities to define both input parameters and outputs (Marcot et al. 2006). BBNs have been used to model other ecological systems associated with high uncertainty (e.g., Amstrup et al. 2010). BBNs have a number of desirable characteristics for ecological modelling:

1. models are presented intuitively as a series of variables or "nodes", parameters or "states" and arrows showing the relationships among them;
2. rather than a purely conceptual model, BBNs are fully parameterized and generate quantitative predictions;
3. BBNs can accept a mix of quantitative and qualitative information, based on both existing data and on expert opinion;
4. outputs are robust to missing data;
5. models can be updated with data as they become available; and,
6. uncertainty can be accommodated explicitly by assigning ranges of probabilities to input parameters.

RESULTS

We included the following input variables in the model (Fig. 2):

1. line of sight distance - distance between helicopters and goats has been documented as an important variable influencing behaviour (Côté 1996, Wilson and Shackleton 2001, Goldstein et al. 2005). Commonly cited intervals were used as states (i.e., parameters).
2. season - we hypothesized that the consequences of behavioural changes are more severe when mountain goats are most physiologically stressed. Energy balance is negative throughout winter because access to preferred forage is limited (Fox and Smith 1988) and moving through snow is energetically costly (Dailey and Hobbs 1989). Lower survival, at least for juvenile mountain goats, is correlated with winter severity (Côté and Festa-Bianchet 2003). The consequences of negative energy balance are likely to increase as the winter progresses.
3. snow depth - snow conditions can differ significantly in different parts of a winter range (i.e., under canopy or at different elevations and aspects), but from an energetic perspective, mountain goats begin to suffer a significant metabolic cost when sinking depths exceed brisket height (Dailey and Hobbs 1989). We

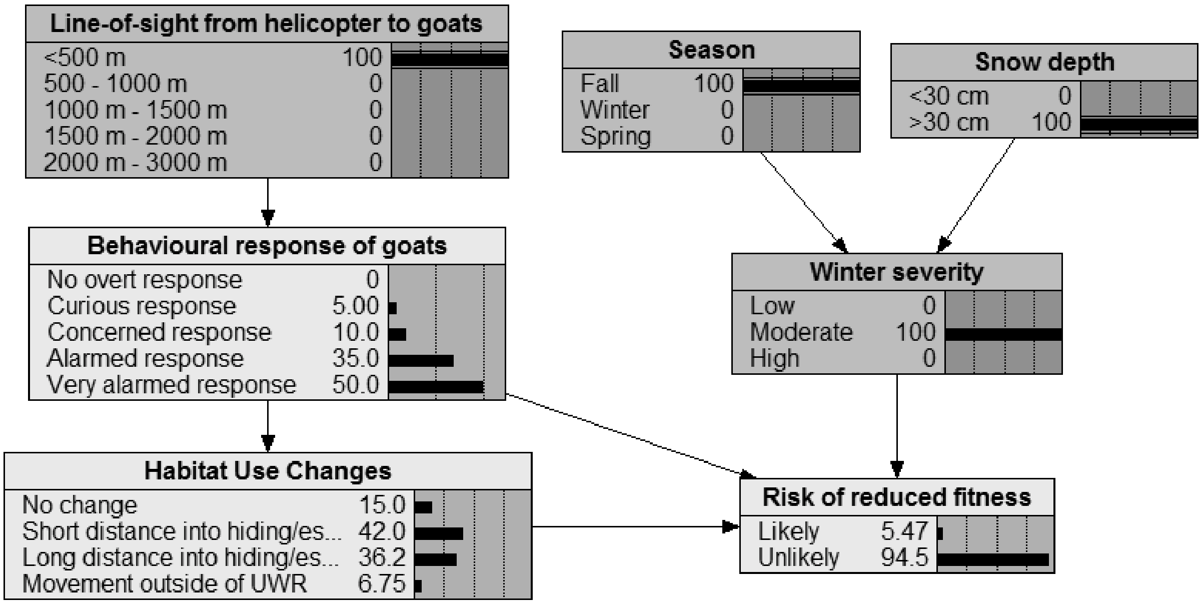

Fig. 2. Bayesian Belief Network developed to describe the hypothesized relationships among helicopter-logging activity, the behavioural responses of mountain goats, and the risk of reduced fitness. In this example output, a distance of <500 m between a helicopter and mountain goats during the fall season with snow >30 cm results in half of the mountain goats exhibiting a "very alarmed response", resulting in a hypothesized 5% risk of reduced fitness.

used >30 cm as the snow depth at which metabolic cost begins to increase. This was based on literature that identified 25 cm as the critical depth for black-tailed deer and the fact that mountain goats are slightly taller than deer (Bunnell 1990). Where 30 cm is the minimum snow depth found on a winter range, mountain goats are unlikely to be able to avoid increased mobility costs, except where snow conditions (e.g., crusting, compaction) enable greater mobility; however, these characteristics are difficult to measure consistently and objectively and were not considered.

Other important variables were considered constants:

4. intensity of helicopter-logging activity - although the frequency of helicopter activity could influence reactions by mountain goats, helicopter-logging activity is an intensive activity in general, requiring helicopter approaches every few minutes. We assumed that effects would saturate quickly; therefore, intensity was considered a constant.
5. duration of helicopter-logging activity - longer exposure to helicopter activity might result in stronger reactions by mountain goats. We parameterized the model assuming an average duration of helicopter-logging operations of 1–2 weeks. Although the maximum behavioural response by mountain goats likely occurs within 1–2 days, the consequences of the response likely increases with duration for the strongest behavioural responses (e.g., movements into sub-optimal habitat). Chronic exposure (i.e., repeated disturbances over several weeks or months) associated with consistent habitat use changes could make permanent abandonment of a winter range more likely. There is also the possibility that individuals could habituate to the activity (Stankowich 2008). This was not considered in the model, which was focused on short-term responses.
6. size of helicopter - the model specifically addressed the use of large helicopters associated with the yarding phase of logging activities (i.e., removing logs from the site with heavy lift helicopters). Some smaller helicopters are also used to support logging operations but we assumed the marginal effect of additional, smaller machines would be minor.
7. relative position of the helicopter - approach angles can influence the reactions of mountain

Table 1. Relative winter severity index, as estimated by season and snow depth in the risk management model for mountain goats.

Season	Snow depth (cm)	Winter severity
Fall	<30	Low
Fall	>30	Moderate
Winter	<30	Moderate
Winter	>30	High
Spring	<30	Moderate
Spring	>30	High

goats and other Capridae to helicopters (Krausman and Hervert 1983, Côté 1996, Frid 2003); however, helicopter-logging generally occurs below the location of mountain goats and helicopter position was therefore considered a constant.

Season and snow depth were summarized in a node called winter severity, which estimated the combined, relative effect of the variables on mountain goat susceptibility to consequences arising from behaviour and habitat changes (Table 1). Winter severity was considered highest for deep snow late in the season when mountain goats are stressed by months of limited mobility and nutritional deprivation.

We estimated the relationship between distance from helicopter-logging activity and mountain goats behavioural changes according to Penner's (1988) classification of responses and available literature (e.g., Côté 1996, Goldstein et al. 2005; Table 2). Expected habitat use changes resulting from behavioural changes by mountain goats were based largely on expert opinion (Table 3).

The risk of reduced fitness was hypothesized to be a function of both the behavioural responses of mountain goats (i.e., risk increases with stronger initial reaction to helicopter-logging activity) and resulting habitat use changes (i.e., the farther animals travel from preferred habitat, the higher the risk), as well as winter severity (i.e., travelling long distances in deep snow in poor condition poses the greatest risk). There was little available literature or experience to quantify these relationships. Our estimates were informed by experience but should be considered hypotheses (Table 4).

The risk of mountain goats moving off a winter range as a result of helicopter activity was hypothesized to be low for all approach distances (Fig. 3), but there was an inflection in the model results at 1000–1500 m. At this distance the probability of mountain goats moving long distances or moving off a winter range was estimated to be 11%. This probability increased to 43% at <500 m.

Risk of reduced fitness was considered acceptably low when <1% (green) and unacceptably high when >4% (red). These limits were inferred from provincial harvest guidelines (BC Ministry of Environment 2010) and reflect that mountain goat populations are very sensitive to mortality (Hamel et al. 2006) and that even small reductions in fitness (from either direct mortality or an increased likelihood of reproductive failure) are likely to have negative population consequences. The risk of reduced fitness was hypothesized to be unacceptably high population consequences. The risk of reduced fitness was hypothesized to be unacceptably high when helicopter-logging activity occurs <1000 m from mountain goats in severe winter conditions,

Table 2. Estimated relationship between separation distances and subsequent behavioural responses, following Penner (1988).

Distance from helicopter-logging to goats (m)	No overt response (%)	Curious response (%)	Concerned response (%)	Alarmed response (%)	Very alarmed response (%)
<500	0	5	10	35	50
500-1000	0	5	15	50	30
1000-1500	10	25	40	15	10
1500-2000	30	40	15	10	5
2000-3000	60	35	5	0	0

Table 3. Hypothesized relationship between behavioural responses of mountain goats to helicopter-logging activity and the relative distance moved by goats. Short and long distances were not defined because of the variation in size of winter ranges.

Behavioural response of goat	No change	Short distance into hiding/escape terrain	Long distance into hiding/escape terrain	Movement outside of winter range
No overt response	100	-	-	-
Curious response	100	-	-	-
Concerned response	100	-	-	-
Alarmed response	-	70	25	5
Very alarmed response	-	35	55	10

Table 4. Hypothesized risk of reduced fitness in the risk management model, based on winter severity, behavioural response of mountain goats, and habitat use changes.

Winter severity	Behavioural responses of goats	Habitat use changes	Unlikely	Likely
Low	No overt response	No change	100	0
Low	Curious response	No change	100	0
Low	Concerned response	No change	100	0
Low	Alarmed response	Short distance into hiding/escape terrain	99.9	0.1
Low	Alarmed response	Long distance into hiding/escape terrain	99.8	0.2
Low	Alarmed response	Movement outside of UWR	99.5	0.5
Low	Very alarmed response	Short distance into hiding/escape terrain	99	1
Low	Very alarmed response	Long distance into hiding/escape terrain	98	2
Low	Very alarmed response	Movement outside of UWR	98	2
Moderate	No overt response	No change	100	0
Moderate	Curious response	No change	100	0
Moderate	Concerned response	No change	100	0
Moderate	Alarmed response	Short distance into hiding/escape terrain	99	1
Moderate	Alarmed response	Long distance into hiding/escape terrain	98	2
Moderate	Alarmed response	Movement outside of UWR	90	10
Moderate	Very alarmed response	Short distance into hiding/escape terrain	95	5
Moderate	Very alarmed response	Long distance into hiding/escape terrain	90	10
Moderate	Very alarmed response	Movement outside of UWR	75	25
High	No overt response	No change	100	0
High	Curious response	No change	100	0
High	Concerned response	No change	100	0
High	Alarmed response	Short distance into hiding/escape terrain	98	2
High	Alarmed response	Long distance into hiding/escape terrain	96	4
High	Alarmed response	Movement outside of UWR	80	20
High	Very alarmed response	Short distance into hiding/escape terrain	90	10
High	Very alarmed response	Long distance into hiding/escape terrain	80	20
High	Very alarmed response	Movement outside of UWR	70	30

and <500 m in moderate winter conditions (Table 5).

DISCUSSION

One reason recommended separation distances between helicopters and mountain goats have varied is because recommendations are often provided without reference to the objective the recommendation is intended to achieve, and/or the degree of precaution applied. For example, an objective to completely prevent changes in mountain goat behaviour resulting from helicopter

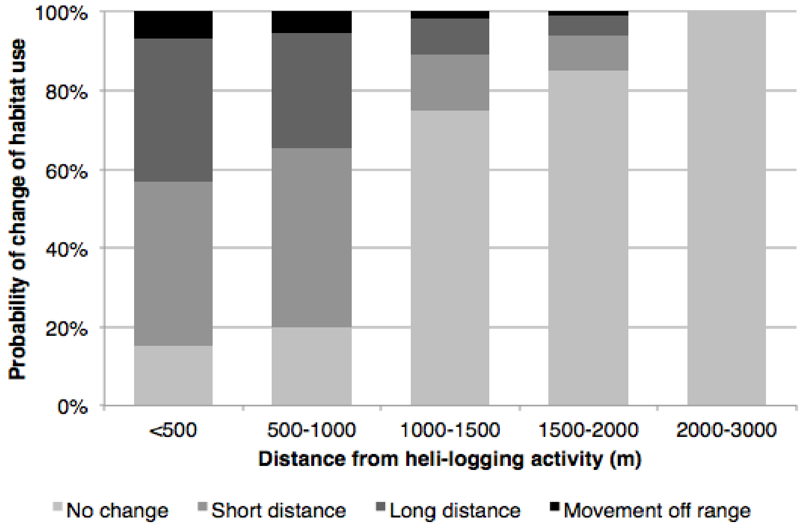

Fig. 3. Relationship between separation distances and the estimated likelihood of changes in habitat use, based on the risk management model.

activity requires a much more precautionary separation distance than an objective that accepts some risk to mountain goats. Without reference to objectives or precaution, recommendations confound the positive (i.e., “what is”) elements of the management problem with the normative (i.e., “what ought to be”). In contrast, our method focused on characterizing the risk to mountain goats associated with different management policies and separating the technical issue (i.e., risk of reduced fitness) from the policy decision (i.e., what level of reduced fitness is acceptable?).

Wildlife managers are often faced with the challenge of managing systems with a high degree of uncertainty. Gaps in the scientific and management literature, as well as limited resources for monitoring and adaptive management trials, necessarily limits the confidence of management decisions. We suggest that the best approach in these circumstances is to develop a working hypothesis in the form of a quantitative model that explicitly documents assumptions and uncertainties. The model can then be used to predict the outcomes of different policy options. These predictions can serve as the basis for adaptive management trials, the results of which can be used to explicitly update the model to ensure that management is always based on the best available information.

Our study represents the first attempt to assess the risk of helicopter-logging to the fitness of mountain goats. We suggest that risk is associated not only with the approach distance of helicopters but also with the severity of winter conditions, which might increase the fitness implications of behavioural changes caused by helicopters. We further suggest that some published separation distances pose a very low risk to the fitness of mountain goats. Although rarely stated, the objective of published recommendations appears to be to minimize the likelihood of behavioural reactions by mountain goats in response to helicopters. This may or may not align with the policy objectives of wildlife agencies.

Because of our reliance on expert opinion, our results are best considered hypotheses to guide current management under uncertainty, and to guide future monitoring and adaptive management.

Table 5. Risk of reduced fitness, based on distance from helicopter-logging activity and winter severity. Risk of <1% was considered acceptably low and >4% unacceptably high.

	Line-of-sight distance from helicopter-logging activity to mountain goats (m)				
Winter severity	<500	500-1000	1000-1500	1500-2000	2000-3000
Low	0.88	0.57	0.19	0.10	0
Moderate	5.47	3.78	1.23	0.66	0
High	9.94	6.95	2.26	1.21	0

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