Does survey effort influence sightability of mountain goats Oreamnos americanus during aerial surveys?

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CURRENT MANAGEMENT

Does survey effort influence sightability of mountain goats *Oreamnos americanus* during aerial surveys?

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Practical techniques to estimate the sightability of mountain goats *Oreamnos americanus* during aerial surveys have not been developed or have been poorly tested. I evaluated sightability of 28 radio-collared goats in two study areas in southeastern British Columbia to assess whether sightability increased with increased helicopter survey effort, and to explore which factors might affect sightability. Three surveys at different survey efforts were conducted in each study area, during which attempts were made to locate collared goats 64 times. I detected no relationship between survey effort in the range tested (1.3-6.1 minutes/km^2) and sightability (38-83%). Sightability averaged 63%. Only animal activity and larger group size influenced goat sightability. Sightability tended to decrease with increased vegetation cover. Survey efforts of $>$ 2.0 minutes/km^2 do not appear to result in higher sightability. For surveys of large areas not well-known to surveyors, a 60-65% sightability correction may be realistic, with a target of approximately 1.5 minutes/km^2 effort.

Key words: aerial survey, census, mountain goats, Oreamnos americanus, sightability, survey effort

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Techniques to accurately estimate mountain goat *Oreamnos americanus* numbers over large remote areas have not been developed (Poole et al. 2000). Ground counts may be more precise than aerial surveys (Fox 1984, Côté & Festa-Bianchet 2003), but are not feasible where study areas encompass thousands of square kilometres. Thus, aerial surveys are most commonly used (Resource Information Standards Committee 2002, Alberta Sustainable Resource Development 2003). Not all goats are observed during aerial surveys (Gonzalez-Voyer et al. 2001), but no regression-based sightability models have been tested for mountain goats, and development of a model for goats would be difficult (Poole et al. 2000). Goat habitat is a heterogeneous mix of alpine meadows, alpine parkland, upper elevation forests, scree slopes and cliffs intermixed with varying amounts of shrubs and trees (Côté & Festa-Bianchet 2003). Variability in group size and environmental and behavioural factors, including sexual differences, would add to model complexity. Reliable mark-resight techniques also have not been well tested, and require a large proportion of the population to be marked to obtain precise results; available studies are limited by no replicates and small sample sizes (Cichowski et al. 1994, Smith & Bovee 1984, Poole et al. 2000, Pauley & Crenshaw 2006). Finally, stratified, double sampling surveys are limited by violations of the assumptions that all goats seen during the initial (standard) survey are seen during the intensive resurvey, and that all goats present in the sample unit are seen during the intensive survey (McDonald et al. 1990, Loranger & Spraker 1994). Thus, no reliable options to accurately estimate goat sightability over large remote areas currently exist.

A host of factors can influence mountain goat survey results and sightability; potentially the most important factors are changes in behaviour and distribution, differential sightability by terrain and vegetation, survey effort, seasonal effects on movement or distribution, and changes in weather conditions. Survey effort is essentially a function of the number, spacing and flight speed of helicopter passes along potential, predefined goat habitats, and can be quantified as time spent per km^2 of survey area. Given the often large areas covered and limited budgets, a quantitative analysis of the effects of survey effort on sightability could contribute to more accurate estimates of goat numbers, and thus assist population management.

In this paper, I examine the influence of survey effort and other variables on goat sightability within two study areas in the interior mountains of southeastern British Columbia. Radio-collared goats were available to test animal sightability under simulated survey conditions. I predicted that sightability would increase with survey effort.

Material and methods

Study area

I selected two study areas based on the availability of goats fitted with radio collars as part of a study designed to examine winter habitat selection (K. Poole, unpubl. data). In each of the St. Mary area in the Purcell Mountains (49° 40'N, 116° 25'W) and in the White area in Rocky Mountains (50° 10'N, 115° 15'W) 14 collared goats were available. In both areas, the terrain is steep and rugged, with valley bottoms down to 1,000-1,150 m a.s.l. and peaks ranging up to 2,850 m in the St. Mary and 3,200 m in the White area. Using aerial helicopter net-gunning in January 2004, 24 goats were captured, and four were captured in November 2004. Summer goat habitats in both areas generally occur in alpine, subalpine and upper-elevation forested areas. Forested stands were comprised of hybrid white spruce *Picea glauca* x *engelmannii*, subalpine fir *Abies lasiocarpa*, lodgepole pine *Pinus contorta* and western larch *Larix occidentalis*, with a transition into parkland and krummholtz at the highest elevations (Meidinger & Pojar 1991, Braumandl & Curran 1992). Whitebark pine *Pinus albicaulis* and alpine larch *Larix lyalli* are common at the highest elevations. The St. Mary area is within the moist climatic region and the White area is in the dry climatic region of southeastern British Columbia (Braumandl & Curran 1992). Compared with the St. Mary study area, the White River area has a greater amount of alpine with more extensive open mountainous ridge lines and 2-3 times the density of goats within potential goat habitat (generally defined as > 1,700-1,850 m a.s.l.; British Columbia Ministry of Environment, unpubl. data).

Sightability surveys

The primary study design was to conduct goat surveys in the areas where collared goats were located, and to alter survey effort while holding constant as many variables as possible. The survey protocol generally followed British Columbia and Alberta total count survey standards (Resource Information Standards Committee 2002, Alberta Sustainable Resource Development 2003). Surveys were conducted on 6 and 8 September 2004, and on 9-15 August 2005. I located all collared goats 1-6 days prior to the start of surveys each year using a Cessna 172, ensuring that aircraft disturbance was kept to a minimum. Survey blocks were then delineated on maps around each collared goat or adjacent collared goats. The blocks were large enough (> 5-10 km^2) to encompass relatively discrete portions of mountain blocks, such that the risk was minimal that the collared individual would move out of the block within days, and there was a high probability that additional, non-collared goats were present in the block.

The original intent was to conduct two surveys by helicopter in each area each year with two independent crews of rear-seat observers surveying each area once each year at different survey efforts. This would have resulted in eight separate surveys. Surveys within each area were spaced over ≥ 2 days to allow goats to redistribute from any disturbance effects of the helicopter (Côté 1996, Goldstein et al. 2005), yet retain similar survey conditions. However, due to inclement weather each area was surveyed only once in 2004, but two surveys of each area were conducted in 2005.

A Bell Jet Range 206B helicopter with rear bubble windows was used for surveys. The same navigator participated in all flights, and the pilot was the same on all surveys within each year. All participants had experience conducting wildlife surveys or were experienced hunters, and each participated in locating mountain goats. I flew contour lines at a speed of 60-120 km/hour, 75-100 m out from the mountain sides, and altered aircraft speed and flight contour spacing depending upon terrain and visibility and to adjust survey effort. I noted survey coverage on 1:50,000 scale topographical maps, and for each goat group recorded the broad habitat type (cliff, rocky, treed), elevation (from the helicopter's altimeter to the nearest 100 feet ~ 30 m), and behaviour of the first animal of the group observed (stationary, i.e. bedded or standing, or active, i.e. walking or running). Cliff habitat included sheer or broken cliffs; rocky habitat incorporated areas dominated by slopes of scree, talus or boulders; and treed habitat included areas dominated by parkland, krummholtz or the upper fringes of continuous tree cover. For each goat group, I also recorded vegetative cover, measured at an oblique angle as the average vegetation hiding cover within a 10 m radius of the first goat sighted in a group (*sensu* Anderson & Lindzey 1996, Quayle et al. 2001). Goat locations and flight track were recorded with a hand-held GPS unit, and were later downloaded to a computer. Surveys were initiated at 07:30-08:00 hour, and all but three were completed by 13:00 hour.

During surveys, the navigator monitored the location of collared goats using telemetry gear attached to the helicopter and audible only to the navigator. The navigator did not attempt to precisely locate collared goats during surveys, but simply listened for them (both antennae). Collars were generally visible from the helicopter, and collared goats not located during coverage of a block were located immediately after the survey of the block was completed; the same data were collected as for goats observed during the surveys. Observers and pilot did not know when a collared goat was nearby, or how many collared goats were in each block. Some movement of goats between consecutive surveys ensured that no participants knew exactly where collared goats were located.

Survey blocks were centred on 6-9 mountain blocks or faces in each area that contained one or more collared goats and other non-collared goats. To ensure standard calculation of coverage, the census area of potential goat habitats was calculated using ArcView (Environmental Systems Research Institute, Redlands California, USA) by placing an approximately 200-300 m buffer around outer flight tracks. Given the comparatively small area surveyed in each sightability block (as dictated by dispersed collared goats and budget limitations), survey effort was slightly higher than usual for broad mountain surveys.

Data analysis

My intent was to explore the relationship between sightability and survey effort, and then to examine independent variables associated with the sightability of goats. I did not intend to build a multiple logistic regression model of goat sightability because I recognized that sample sizes were small, and I did not capture the range of variables likely required for an accurate model. I used linear regression to compare sightability, average survey effort and observed density for each survey. To examine the impact of number of passes on vertical distribution of goats, I plotted goat distribution by elevation and compared elevations of goat groups using a t-test.

I used likelihood ratio χ^2 analysis (G-test) for discrete variables and univariate logistic regression for continuous variables to test the relationship between independent variables (group size, sex, groups with and without kids, time of day, habitat type, vegetative cover, behaviour and survey effort) and the dichotomous dependent variable (observed or missed). I used Spearman correlation coefficients to evaluate the correlation between variables. All analyses were conducted using SAS software (SAS Institute 1997).

Table 1. Summary of mountain goat sightability survey results for White and St. Mary study areas, southeastern British Columbia, during 2004-2005.

Date	Area	No. of blocked surveyed	Survey area (km^2)	Survey effort (minutes/km^2)	No. of goats observed	Observed density (goats/km^2)	No. of collared goats present	Sightability (%)
6 September 2004	White	8	91	1.3	126	1.39	10	50
8 September 2004	St. Mary	9	155	1.3	70	0.45	12	83
9 August 2005	White	6	36	3.0	82	2.28	8	63
11 August 2005	White	7	24	6.1	68	2.82	9	56
10 August 2005	St. Mary	9	49	3.4	19	0.39	13	38
15 August 2005	St. Mary	9	91	1.9	54	0.60	12	83

Results

Six sightability surveys were completed using 28 different collared mountain goats (12 males (M) and 16 females (F)). For each survey, 8-13 goats were available. Summing all surveys, I attempted to locate collared goats 64 times (30 M, 34 F). During surveys, winds were subjectively rated as calm or light, and light conditions were good. Cloud cover varied from 0 to 100%.

There was no relationship between survey effort and sightability ($F_{1,5} = 0.78$, $P = 0.43$, $r^2 = 0.16$; Table 1 and Fig. 1). Survey effort ranged within 1.3-6.1 minutes/km^2; all but one survey were conducted at $\leq$ 3.4 minutes/km^2. Sightability averaged 63% (range: 38-83%; see Fig. 1). There was no linear relationship between sightability and density of goats observed during surveys ($F_{1,5} = 0.21$, $P = 0.67$).

Goat groups were observed over an 850-m elevation range in the St. Mary and a 1,100-m range in the White study area (data for the 2005 surveys are provided in Fig. 2). Using data from 2005, goats were observed at lower elevations in the St. Mary study area (2,180 ± 25 m (SE), N = 51) than in the White study area (2,320 ± 33 m, N = 51; t = 3.30, df = 100, P = 0.0013). Sightability tests in the St. Mary recorded the two highest and the one lowest sightability among surveys (see Fig. 1).

Univariate analysis on individual collared goats suggested that active (walking or running) goats were more visible than stationary (bedded or standing) goats, and groups sizes > 3 tended to be more visible than groups of 1-3 goats (Table 2). Although not significant, sightability decreased with increasing vegetative cover and treed habitat types. Sex, group composition and time of day did not affect sightability. I found a negative, and possibly spurious, relationship between vegetative cover and group size (r = -0.30, P = 0.018).

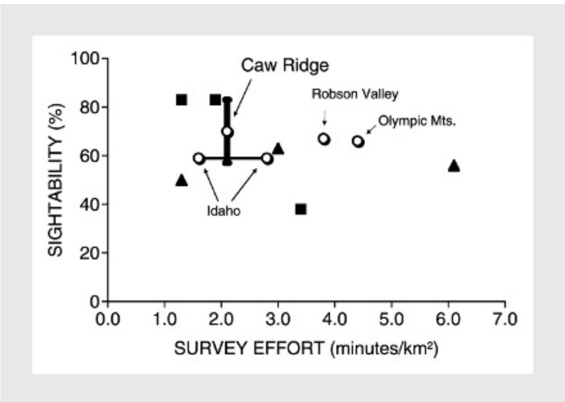

Figure 1. Sightability (in %) of collared mountain goats and survey effort (in minutes/km^2) for the St. Mary (■) and White (▲) study areas, southeastern British Columbia. Open circles (○) represent sightability data from other studies (see text for references and details). Caw Ridge data are represented by the mean and range for 11 surveys. Idaho data represent the modelled sightability from two surveys of differing effort.

Discussion

Within the range of survey effort tested (1.3-6.1 minutes/km^2), effort was not correlated with sightability of collared mountain goats. I compared sightability over the range of survey efforts used during surveys designed to cover large, remote

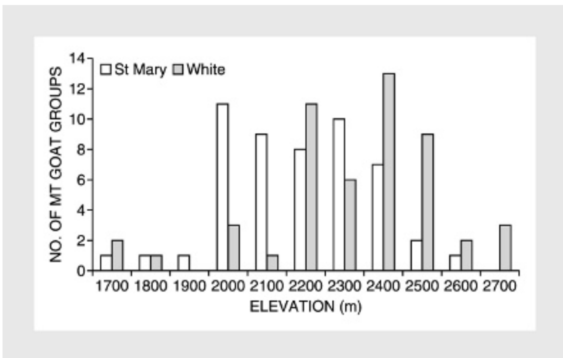

Figure 2. Elevation (in m) of goat groups observed in the St. Mary (N = 51) and White (N = 51) survey areas, southeastern British Columbia, in August 2005.

Table 2. Univariate analyses of independent variables measured during helicopter sightability trails of 64 mountain goats, southeastern British Columbia, during 2004-2005. Likelihood ratio χ^2 analysis (G-test) was used for discrete variables and univariate logistic regression for continuous variables. Category divisions among continuous variables were arbitrarily divided into approximate equal sample sizes among categories.

Variable	N	% seen	χ^2	P
Discrete				
Sex			1.37	0.24
Male	30	70		
Female	34	56		
Group composition			1.31	0.25
With kids	18	50		
No kids	41	66		
Animal activity			3.84	0.05
Stationary	23	48		
Active	37	73		
Habitat type			2.14	0.34
Cliff	26	65		
Rock	18	72		
Treed	20	50		
Continuous				
Group size			3.46	0.06
1	30	57		
2-3	22	59		
4-14	12	83		
Time of day (hour)			0.01	0.98
08:00-09:59	23	57		
10:00-11:59	25	68		
12:00-15:11	16	63		
Vegetative cover (%)			0.72	0.40
0	28	68		
1-20	19	63		
21-70	16	56		
Survey effort (minutes/km^2)			0.80	0.37
0.8-1.5	18	67		
1.6-3.0	25	76		
3.1-8.1	21	43		

areas, as is needed for population management, with higher effort to see whether sightability increased. Survey effort averaged 1.5 minutes/km^2 (range: 1.0-1.9 minutes/km^2) during five surveys covering large areas conducted recently in southeastern British Columbia (census zones of 600-2,200 km^2; British Columbia Ministry of Environment, unpubl. data). I conclude that variation in sightability due to other factors is so large as to obscure this relationship unless very low-effort surveys are tested.

Where published surveys have used collars or marked goats, sightability using helicopters has ranged from 59% (Pauley & Crenshaw 2006; based on modelling of initial sighting probability of undisturbed goats) to 67-70% (Cichowski et al. 1994, Poole et al. 2000, Gonzalez-Voyer et al. 2001) in interior mountain goat populations. Cichowski et al. (1994) observed 68% of 28 mountain goats marked with paint balls, but did not report survey effort. Poole et al. (2000) observed 67% of 12 collared goats in the Robson Valley at an average survey effort of 3.8 minutes/km^2 (see Fig. 1). Pauley & Crenshaw (2006) marked approximately 50 goats with paint balls in Idaho during two trails with survey effort that varied within 1.6-2.8 minutes/km^2, but the sightability was calculated from a model, negating calculation of effort specific sightability. Sightability of goats during annual surveys conducted over 11 years on Caw Ridge in west-central Alberta averaged 70%, but ranged within 55-84% during any one survey (Gonzalez-Voyer et al. 2001). Caw Ridge is a well-studied population residing on a single, small (28 km^2) block of high hills with a high-density goat population (> 4 goats/km^2) that can be easily covered by a single flight around the perimeter. Survey effort was consistent among years at roughly 2.1 minutes/km^2 (K. Smith, Alberta Fish and Wildlife Division, Edson, Alberta, pers. comm.). In the coastal Olympic Mountain Range, Washington, eight surveys conducted over three years (at 4.4 minutes/km^2 average survey effort) estimated a sightability of 66% (Houston et al. 1986).

All other variables being equal, I suspect that the relationship between survey effort and sightability initially follows a rough logarithmic curve, as described for moose *Alces alces* surveys by Gasaway et al. (1986: Fig. 9). These researchers suggested that sightability increases rapidly from nil to moderate search effort, then levels out as search effort increases further. Plots of elevation of goats suggest that a single pass with roughly 125-150 m wide vertical transects on both sides of the helicopter would miss well over half of the goat groups present in each area (see Fig. 2).

Unlike moose surveys in interior Alaska (Gasaway et al. 1986), my data suggest that many goats will not be observed even at very high effort. Mountain goats may respond to helicopter disturbance at distances of up to 2 km, and therefore with slowly approaching aircraft may have ample time to hide or flee (Côté 1996, Goldstein et al. 2005). We observed disturbed goats tucking into crags and even caves in cliffs, and hiding under the base of trees in more forested areas.

Marking goats over large areas is cost-prohibitive (e.g. collaring animals; Poole et al. 2000) or poorly tested (e.g. paint ball marking; Cichowski et al. 1994, Pauley & Crenshaw 2006). Changes in behaviour as a result of marking can be accommodated in mark-resight surveys with three or more survey occasions (Pauley & Crenshaw 2006), but such effort is not practical or cost-effective over large remote areas. Lacking marked goats, one potential option to determine sightability correction is double-sampling, which involves intensive resurvey of a number of randomly selected survey units within the study area (*cf.* McDonald et al. 1990, Loranger & Spraker 1994 for Dall's sheep *Ovis dalli*, Gasaway et al. 1986 for moose). This would involve returning to a survey unit either immediately or soon after the initial survey to resurvey (and remap) goat distribution and numbers, using perhaps twice the survey effort as initially used. However, this technique assumes that very high effort will assure the inventory of nearly all animals in a block (Loranger & Spraker 1994, Strickland et al. 1994). My data suggest that effort is not highly explicative, and, hence, the method is of little value for goat inventories. Re-flying the blocks immediately after an initial survey may result in lower counts because of animal behaviour, and increases overall stress on individuals. Movement over a period of days, potentially off the survey units or mountain blocks, or in or out of the tree line where sightability might vary, may negate the assumptions required to validate mark-resight estimates (Caughley 1977, Smith & Bovee 1984, Cichowski et al. 1994).

Group size has been previously suggested as a significant variable explaining visibility bias to detect mountain goats (Strickland et al. 1994) and elk *Cervus elaphus* (Samuel et al. 1987, Cogan & Diefenbach 1998, McCorquodale 2001), and animal activity has been shown to influence the probability of seeing mule deer *Odocoileus hemionus* (Unsworth et al. 1994), elk (McCorquodale 2001) and bighorn sheep *Ovis canadensis* (Bodie et al. 1995). Vegetative cover figured prominently in sightability modelling for a number of large ungulates (for moose: Anderson & Lindzey 1996, Quayle et al. 2001; mule deer: Unsworth et al. 1994; elk: Samuel et al. 1987, Cogan & Diefenbach 1998, McCorquodale 2001), and will likely contribute to sightability modelling for mountain goats after testing with greater sample sizes. Most models developed for ungulates do not address topographic variables associated with rugged, mountainous topography, including helicopter position, and it is likely that at least some of these variables would ultimately figure prominently in models of goat sightability (see Bodie et al. 1995 for bighorn sheep).

Implications

My results are consistent with those of Gonzalez-Voyer et al. (2001) at Caw Ridge, and suggest that aerial surveys of mountain goats appear to be useful only as rough-trend indicators of major changes in population density. It is, however, encouraging that although sightability in individual survey results often vary widely, study means converge to a range of 60-70% (see Fig. 1).

The results suggest that a very high survey effort may not increase sightability, but may in fact decrease sightability. Gonzalez-Voyer et al. (2001) suggested that an average sightability of about 70% may apply widely to mountain goat helicopter surveys. However, the figure obtained from Caw Ridge may not be readily comparable to those of other areas, given the high familiarity of the study population to the observers, and the relatively simple topography (M. Festa-Bianchet, University of Sherbrooke, Québec, pers. comm.). Other studies conducted at moderately high survey efforts established 66-67% sightability correction (Houston et al. 1986, Poole et al. 2000). I obtained an average sightability of 63%. For surveys of large areas not well known to surveyors, a 60-65% sightability correction appears realistic.

To minimize changes in sightability among surveys and areas, researchers should standardize as many variables as possible, including aircraft type, observer expertise, seasonal and daily timing, weather conditions and survey effort. Depending upon terrain and visibility, approximately 1.5 minutes/km^2 may be a reasonable target of effort to attain over large areas, as higher efforts do not appear to increase sightability (see Fig. 1). Until more precise estimates of sightability are available, to establish reliable estimates of trend in populations frequent surveys over small, representative blocks of goat habitats may provide an alternative to infrequent surveys of large areas.

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