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MOUNTAIN GOAT INVENTORY IN THE ROBSON VALLEY, BRITISH COLUMBIA

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Abstract: A random sample unit survey using sightability correction was used to estimate mountain goat (*Oreamnos americanus*) population size along the Robson Valley in east-central British Columbia in August 1998. Twenty random sample units (12.4 ± 0.67 [SE] km^2 area) were surveyed in a 2,707-km^2 census zone above the 5,500-foot (1675 m) contour line. Standard helicopter survey techniques were employed to thoroughly search each unit (mean survey effort of 3.8 ± 0.21 min/km^2). Twelve radio-collared goats within the census zone provided sightability correction. We counted 127 mountain goats in the 20 units, covering 248 km^2 (9.2% of the census zone). The uncorrected population estimate for the census zone was 1,400 ± 260 goats (95% CI 900 to 1,900), and the mean density was 0.51 goats/km^2. Observers saw 8 of 12 radio-collared goats (67%), giving an adjusted population estimate for the census zone of 2,100 (95% CI 1,200 to 3,800), and an adjusted density of 0.77 goats/km^2. Accuracy and precision of future surveys could be increased by accurate stratification, sampling more units, using more marked (collared) goats, and ensuring that the marked segment of the population better reflects the composition of the census population.

Techniques to accurately estimate mountain goat (*Oreamnos americanus*) numbers in large remote areas are lacking. Practical sightability models or a reliable mark/resight or double sampling methodology have not been well-tested (Resources Inventory Committee 1997). Goats often occur in heterogeneous alpine and subalpine habitats, goat group size and habitat use are highly variable even within survey zones, and study area stratification is often difficult because prior knowledge of goat distribution is lacking. The heterogeneous nature of mountainous terrain and the frequency of forest use by the survey population likely affect sightability (Houston et al. 1986). Estimates of the proportion of goats seen using standard aerial survey techniques were about 68% in 2 studies (Cichowski et al. 1994, Gonzalez-Voyer et al. 2001), but may range as low as 30% (Hebert and Langin 1982, Smith 1984, Smith and Bovee 1984). Mark-resight estimations using radio-collars (46% sightability; Smith and Bovee 1984) and paint-marking (Cichowski et al. 1994) have been attempted on goats, however more testing is needed. The current British Columbia (B.C.) standard for goat inventory is a total count with accuracy confirmed by mark-resight (Resources Inventory Committee 1997).

The mountains surrounding the Robson Valley in east-central B.C. appear to contain a moderate to plentiful abundance of mountain goats, however, total count surveys have only been conducted on small areas within the region (Hebert and Smith 1986; B.C. Ministry of Environment, Lands and Parks (MELP), Prince George, unpubl. surveys). Although hunter harvest of goats in the area appears to be relatively light (averaging about 15 goats/year; MELP, Prince George, harvest statistics), concerns with the impacts of expanding forestry development prompted initiation of a radio-collaring study in 1997 that is examining low elevation forest use (Poole 1998, Poole and Heard in 1998). Our objectives were to estimate mountain goat numbers within the region and to test a new technique (random sample unit survey using sightability correction provided by radio-collared goats) to derive this estimate.

STUDY AREA

The Robson Valley mountain goat study area flanks the Rocky Mountain Trench, which separates the Rocky Mountains to the east and the Cariboo Mountains to the west. The area is made up of 4 of biogeoclimatic zones: Sub-Boreal Spruce (SBS) and Interior Cedar-Hemlock (ICH) zones in the Trench, through the Englemann Spruce-Subalpine Fir (ESSF) zone to the Alpine Tundra (AT) zone with increasing altitude. Treeline is between 1900-2150 m (6,250-7,050 ft). Climate varies with elevation. Mean July and January temperatures for Valemount, located in the Trench at 800 m roughly in the centre of the study area, are 15.8 and –11.0°C, respectively, with an average of 503 mm of precipitation annually (Environment Canada climate normals, unpublished data). In the Trench and valley edges hybrid white-Engelmann spruce (*Picea glauca* x *engelmannii*), subalpine fir (*Abies lasiocarpa*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) are the dominant trees, with extensive stands of lodgepole pine (*Pinus contorta*) due to frequent fire disturbances (MacKinnon et al. 1992). Higher up the mountainsides spruce, subalpine fir and lodgepole pine dominate, with scattered stands of whitebark pine (*Pinus albicaulis*) at the highest elevations. Douglas-fir (*Pseudosuga menziesii*) trees are found throughout the area. In the AT zone conifers are present only in stunted krummholz forms.

The study area was selected to include the front ranges off the Robson Valley, where most hunting effort was concentrated, and all mountain blocks (relatively discrete areas of alpine surrounded by lower elevation forested habitat) containing radio-collared goats (Fig. 1). Mountainous habitat to the southwest of McBride was excluded because of a wildfire and large amount of helicopter activity at the time of the inventory. We used lakes, rivers, large glaciers and height of land to bound the 6,400 km^2 study area. Within the study area we selected a census zone above the 5,500-foot (1,675 m) contour line because, A) this contour bounded the lower limit of the summer distribution of radio-collared goats (Poole 1998), B) there were few cliffs below this level, C) the 5,500-foot contour line was readily identified on topographical maps, and D) the altimeter of our helicopter was in feet. The census zone covered 2,707 km^2, and included portions of B.C. MELP wildlife management units (WMU) 7-2, 7-3, and 7-4.

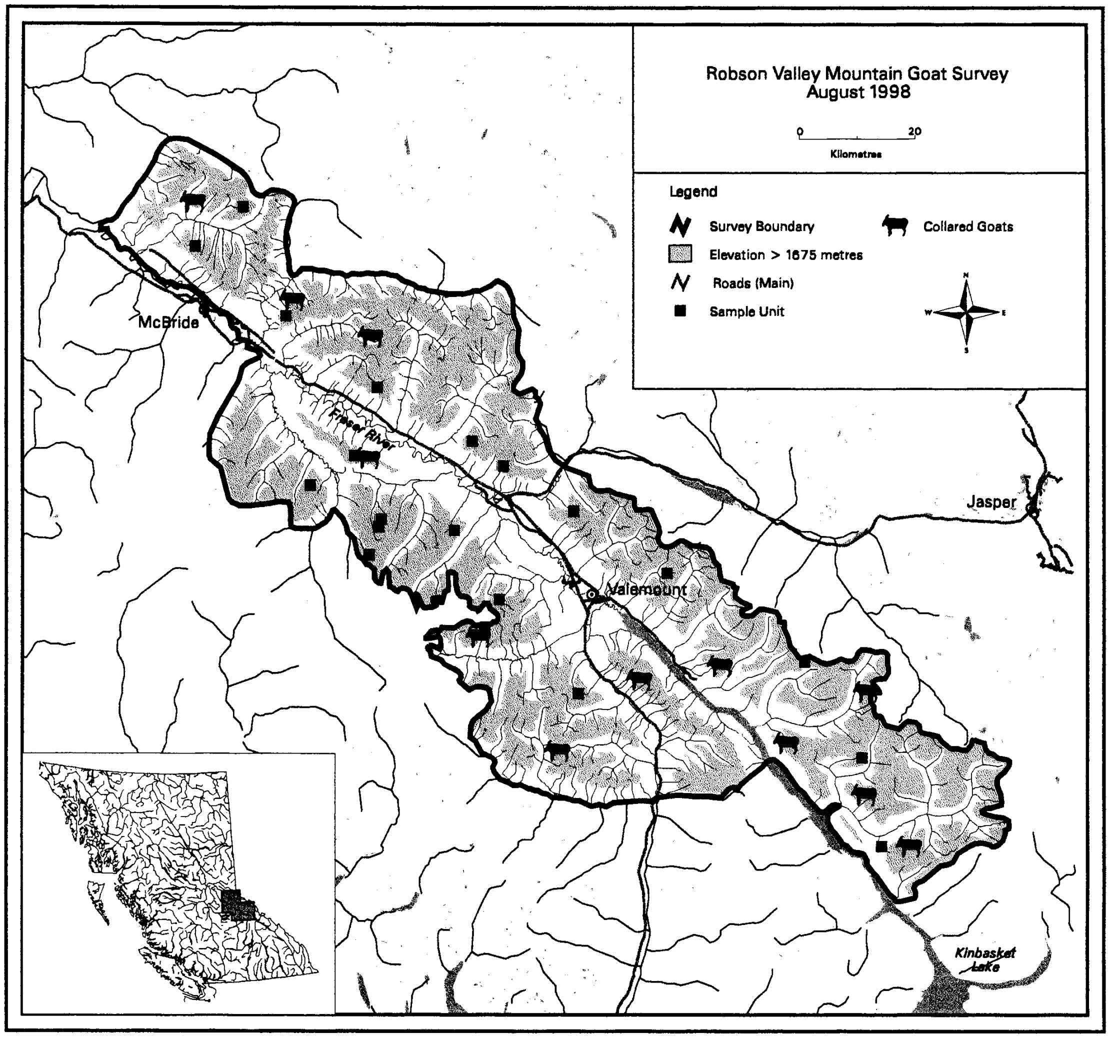

Fig. 1. Robson Valley mountain goat survey showing study area (heavy line), census zone (gray shading), sample units (boxes) and radio-collared goats (goat symbol), 17-21 August 1998.

METHODS

Sampling strategy

We did not stratify the census zone because we had no reliable prior knowledge of mountain goat distribution. We selected sample units using a random numbers table to generate points on a survey map. All points located within the study area were used; points located below the 5,500-foot level were moved up-slope into the census zone. We used these points as the starting point for the survey of each sample unit. This method is not strictly appropriate (Caughley and Sinclair 1994), but worked well in this study because sampling intensity was low. We did not randomly select from among predefined sample units because of the time and cost required to conduct this for the entire census zone.

We conducted the census between 17 and 21 August 1998. We used a Bell 206B Jet Ranger helicopter with pilot, navigator, and 2 observers. The pilot and navigator remained the same throughout the census but observers changed. All occupants participated in locating mountain goats. Starting at the lowest elevation, we flew 100-150 m contour lines at 60-90 km/hr, 50-75 m out from the hillsides. Sample units were surveyed for 35-55 minutes, so that discrete units were covered, generally entire mountain blocks or valleys. We determined boundaries of sample units by using obvious features on the topographic maps, generally height of land between drainages. Sample unit shape varied with terrain, and we determined the size of individual units using a GIS. Sample units did not overlap. We mapped flight lines, survey coverage and location of goats on 1:50,000 topographical maps and recorded the elevation (to the nearest 100 feet) of the goat group from the helicopters altimeter. We classified goats only into kids and adults (yearlings and older) based on body size (B. L. Smith 1988) to reduce survey time, to minimize harassment (Côté 1996), and because researchers familiar with classification from aircraft agree more detailed age and sex classification is not reliable (Houston et al. 1986, Stevens and Houston 1989, Gonzalez-Voyer et al. 2001, S. Coté, Université de Sherbrooke, personal communication).

Sightability correction

On 16 August all 12 radio-collared mountain goats (10 nannies and 2 billies) in the census zone were located by the navigator using a fixed-wing aircraft. During the subsequent 5-day census an attempt was made to locate each radio-collared goat. The navigator was able to monitor goat location using telemetry gear attached to the helicopter and audible only to the navigator. We conducted 12 sightability tests to estimate the proportion of radio-collared goats that observers see under survey conditions. Sightability test plots were centred near the last location of a radio-collared goat, and survey of these blocks was conducted as if they were a standard sample unit. We believe there was no bias in the chances of seeing a collared goat compared to any unmarked goat because we started each sightability test sample unit survey at a defined (topographic) edge of the unit (away from any marked goat), and we attempted to make sample unit coverage even in all surveying. In most cases the observers were unaware that they were being tested for sightability (i.e., that there was definitely a goat nearby). Three radio-collared goats happened to be in random sample units. We did not use mountain goat count data from the sightability test plots for density or composition calculations.

To correct for the sightability bias, we estimated the fraction of radio-collared goats seen by observers in test plots, $p_1=m_1/n_1$; where m_1 is the number of radio-collared goats that were seen by the observers, and n_1 is the number of radio-collared goats in the test plots. The variance of p_1 was based on the binomial distribution, var = pq/n because each radio-collared goat was an independent sample (Snedecor and Cochran 1967).

Data analysis

We calculated the observable population estimate and its variance based on Jolly (1969) for unequal sized sample units where the maximum number of sample units in the census zone was estimated by dividing the average sample unit size into the area of the census zone. The census zone population estimate is equal to the observable population estimate divided by p_1 (the fraction of radio-collared goats seen during the sightability tests). Because the population estimates were not normally distributed but right skewed (Caughley and Sinclair 1994), we calculated the 90% confidence intervals for all estimates using a Monte Carlo simulation model with 5,000 trials.

RESULTS

We counted 127 mountain goats in 54 groups in 20 sample units, covering 248 km^2 (9.2% of the census zone). Only 1 sample unit had no goats present and the maximum unit count was 17 animals (Fig. 2). Group size ranged from 1 to 10 with a mean (± SE) group size of 2.4 (± 0.31). "Typical" group size, an animal-centred measure of the group size within which the average animal finds itself (Jarman 1974, Heard 1992), was 4.5 (± 0.29). Even though 74% of groups consisted of 1 or 2 animals, 40% of the animals were in groups ≥ the typical group size (Fig. 3). Mean time on each sample unit was 44.7 ± 1.63 minutes and mean area covered for each sample unit was 12.4 ± 0.67 km^2, giving a mean survey effort of 3.8 ± 0.21 min/km^2 (n = 20). The naïve (uncorrected) population estimate for the census zone was 1,400 ± 260 goats (95% CI 900 to 1,900), and the mean density was 0.51 goats/km^2. Extrapolated to the entire study area, the mean density was 0.22 goats/km^2.

Observers saw 8 of 12 radio-collared goats (67%), giving an adjusted population estimate for the census zone of 2,100 (95% CI 1,200 to 3,800), and an adjusted density of 0.77 goats/km^2. Mean group size of collared goats was 3.3 (± 0.84), and ranged from 1 to 9 goats (n = 11; 1 collared goat was not observed after the sightability trial, despite intensive effort). Fifty-five percent of the collared groups consisted of 1 or 2 goats. Mean group size did not differ between censused goats and collared goats (t = 2.0, P = 0.24).

Kids comprised 25% (± 3.4%) of censused goats. The elevations of censused goats and radio-collared goats were almost identical (Table 1). Most censused goats were found in the 7,000-7,400 foot band (Fig. 3). Groups with kids were found at the same elevations as groups without kids (Table 1; t = 1.1, P = 0.28). Mean number of adults in groups with kids (2.8 ± 0.43) was greater than adult only groups (1.1 ± 0.06; t = 3.8, P = 0.0012). Similarly, typical group size (kids removed) was also greater for groups with kids compared with groups without kids (4.1 ± 0.29 vs. 1.3 ± 0.07; t = 9.5, P = 0.0001).

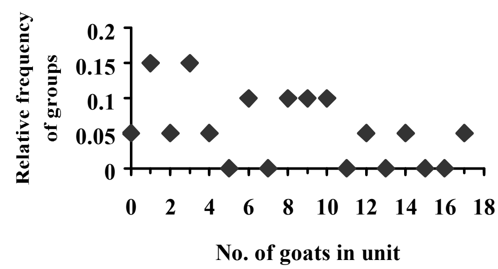

Fig. 2. Relative frequency distribution of number of mountain goats in sample units (n = 20), in the Robson Valley, 17-21 August 1998.

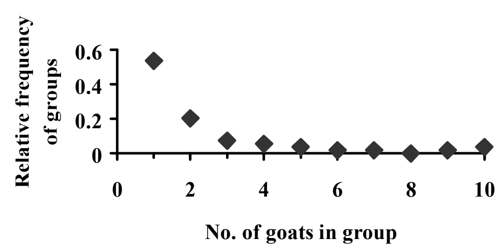

Fig. 3. Relative frequency distribution of mountain goat groups (n = 54), in the Robson Valley, 17-21 August 1998.

Table 1. Elevation of mountain goat groups observed during the census and of radio-collared goats used for sightability correction, Robson Valley, 17-21 August 1998. Three of the radio-collared goats were counted during the census, and are shown in both collared and censused goat groups.

	n	Mean (SE) elevation (ft)	Median elevation (ft)	Min. elevation (ft)	Max. elevation (ft)
Collared goats	12	6,960 (183)	7,000	5,900	7,800
Censused goats	54	6,970 (73)	7,000	5,500	8,100
Non-kid groups	34	6,910 (92)	7,000	5,500	8,100
Kid groups	20	7,080 (120)	7,100	6,000	7,900

DISCUSSION

A number of assumptions must be met to validate mark-resight estimates (Caughley 1977), most of which were likely met in the current study (i.e., there was geographic and demographic closure, no loss of collars, no overlooked collars [marks], goats were not counted more than once, and aerial samples were independent). We observed minimal movement of collared goats from immediately before the survey to during the survey, and the survey was conducted over a short period of time, thus it is unlikely that there was more than a minute amount of movement of goats into or out of the census zone or among sample units. However, the assumption of equal catchability (the collared goats were representative of the "true" population) may have been partially violated. Billies comprised only 2 of the 12 collared goats. Since group size has been suggested as a significant variable explaining visibility bias to detect mountain goats (Strickland et al. 1994) and other ungulates (Samuel et al. 1987), group size of billies is likely smaller than nanny-kid groups during summer (Wigal and Coggins 1982), and billies likely make up roughly one third of the true population (K. G. Smith, personal communication), our observed sightability may have been biased high. Support for this conclusion is given by observers sighting only 1 of the 4 radio-collared goats occurring as single animals, and all of the 7 collared goats in groups (>1 goat). More collars would have increased the precision of the population estimate.

Noteworthy is the fact that the proportion of marked goats observed during our study (67%) is very similar to proportions derived independently in other interior mountain goat populations using slightly different techniques (68%; Cichowski et al. 1994, Gonzalez-Voyer et al. 2001). The sightability of goats in coastal populations appears to be considerably lower (30-46%; Hebert and Langin 1982, Smith 1984, Smith and Bovee 1984). A number of factors contribute to goat sightability, but 65-70% sightability may serve as a standard for interior populations under "normal" survey conditions.

Population estimates based on mark-resight estimators are expensive to conduct because a reasonable sample of collared animals is required. Using a logistic regression estimator, correction factors are applied to each group observed during surveys (Anderson and Lindzey 1996). While a logistic regression-based sightability model may provide more practical and cost-effective population estimates, we suggest that it would be difficult to develop a mountain goat sightability model based on vegetation cover (as in Samuel et al. 1987, Anderson and

Lindzey 1996, Anderson et al. 1998) and terrain/topography (cliff size, shape and morphology). The study area is a heterogeneous mix of alpine meadows, shrubs, krummholtz, upper elevation forests, scree slopes, and varying-sized cliffs with varying degrees of shrubs and/or trees intermixed. Confounding variability in group size and environmental and behavioral factors, including sexual differences, would add to model complexity. A significant number of collared mountain goats would be required to obtain such visibility curves, and the applicability of such a model to other mountainous regions in B.C. would require verification.

Stratified, double sampling involving fixed-winged (Super Cub) surveys and logistic regression and Jackknifing procedures are currently used to estimate Dall's sheep (*Ovis dalli*) and mountain goat population size in Alaska (McDonald et al. 1990, Loranger and Spraker 1994). However, this technique will accurately correct visibility bias only when all goats seen during the initial (standard) survey are seen during the intensive resurvey, and when all goats present in the sample unit are seen during the intensive survey (Poole et al. 1998); neither assumption is generally met (Loranger and Spraker 1994, Strickland et al. 1994).

A stratified random survey design using fixed-wing reconnaissance flights has been used previously to survey mountain goats (Houston et al. 1986, van Drimmelen 1986). Houston et al. (1986) used previous knowledge of goat distribution to delineate 4 strata in the Olympic Mountains, Washington, but still had highly variable counts in their medium density stratum. In the Telkwa Mountains of west-central B.C., stratification was based on the length of steep cliff habitat, forage availability and vegetative community (van Drimmelen 1986). Accurate stratification enabled time savings of reduced effort in low strata, however high (57%) coverage of the 640 km^2 area was required to obtain a confidence interval of <20% of the estimate (90% confidence level). Even in hindsight, we saw no way to accurately stratify our study area, although goat density appeared to be slightly higher in the quarter of the census zone north and east of Highway 16.

The range in elevation covered by the collared goats was similar to that found in the census population, suggesting that our census zone covered a majority of the goats in the study area. Some cliffs are found below 5,500 feet elevation and have been used by the study goats, but generally not during summer (Poole 1998).

Uncorrected goat densities (0.51 goats/km^2 for the census zone, 0.22/km^2 for the entire study area) obtained during this study were generally higher than uncorrected densities (mean 0.15 goats/ km^2; range 0.08-0.31 goats/km^2) obtained from helicopter surveys (primarily conducted in 1982 and 1983) in 6,280 to 1,170 km^2-study areas in interior B.C. (Hebert and Woods 1984). Using stratified random sampling, van Drimmelen (1986) estimated 0.40 goats/km^2 in 640 km^2 of alpine and sub-alpine in the Telkwa Mountains in northwest B.C. Using a mark-resight method, Cichowski et al. (1994) estimated 0.87 goats/km^2 in a 324-km^2 area in the Babine Mountains of northwest B.C. We calculated an uncorrected density of 0.34 goats/km^2 from data reported from a total count survey conducted in a 6,400 km^2 area in the Hazelton and Coast mountains of western B.C. (Demarchi et al. 1997), approximately 50% higher than our uncorrected study area density. Comparisons of goat densities among studies must be conducted cautiously because of differences in study area size and definition, study design, survey timing and intensity, and other factors.

The proportion of kids we observed (25%) was higher than the percent kids observed during summer/early fall surveys in the Babine Mountains (17-18%; Cichowski et al. 1994), the Hazelton and Coast mountains (19%; Demarchi et al. 1997), and interior B.C. (15-23%; McCrory 1979, and 21%; Hebert and Woods 1984). However, direct comparisons may not be valid because kid estimates vary with survey techniques and time of year (Festa-Bianchet et al. 1994).

The number of goats shot in WMUs 7-2, 7-3 and 7-4 has remained relatively constant over the past 10 years, averaging 14.8 (± 1.41) goats annually, with no linear trend ($r^2 = 0.04$, $P = 0.6$). The proportion of billies in the kill averaged 59% (± 4.9%). The kill rate of 0.7%/yr (or 1.1%/yr using the lower 95% CI population estimate of 1,200 goats), is likely below the maximum sustainable yield for most populations (Houston and Stevens 1988, K. G. Smith 1988). Range-wide population and hunter kill estimates cannot be used to manage specific mountain blocks because of variable hunter effort and access across zones.

MANAGEMENT RECOMMENDATIONS

We suggest that a random sample unit survey has the potential to be used broadly for surveying mountain goats, especially over large areas where complete coverage is impractical. A number of changes would increase the accuracy and precision of future surveys:

1. Accurate stratification of sampling units into areas of similar density and the appropriate allocation of effort among strata (Caughley and Sinclair 1994).
2. Increase sampling intensity and provide a greater number of marked (collared) goats. Both the number of sample units and the number of goats marked would have to be tripled to obtain a coefficient of variation of about 0.1, an acceptable result for wildlife surveys (Sinclair 1972).
3. Ensure that the marked segment of the population reflects the composition of the census population.
4. Sample units should be predefined, and then those to be flown selected randomly (Caughley and Sinclair 1994).

Although it would be expensive and logistically difficult to develop, construction of a logistic regression sightability model may ultimately be the most practical and cost-effective approach for mountain goats inventories in B.C. (I. Hatter, B.C. MELP, Victoria, personal communication). However, sufficient numbers of trials with marked goats are required to run the sightability trials required to develop and quantify such a model. Data from moose (*Alces alces*) modeling suggest that at least 80, preferably >100 trials are required to produce a goat sightability model with reasonable variance and broad applicability (Anderson and Lindzey 1996, Anderson et al. 1998, MacHutchon 1998).

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