Stone's Sheep Demographics in the Sulphur / 8 Mile Project Area, Northern British Columbia, Winter 2006/2007

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Abstract: One of the primary objectives of the S8M Stone's Sheep Project in northern British Columbia was to assess Stone's sheep (*Ovis dalli stonei*) population size, demographics, and stability, in order to provide a baseline for oil and gas pre-tenure plan management direction. Two population inventories were conducted, in December 2006 and March 2007. The censuses included all areas ≥ 1,400 m (approximate tree line) within the bounds of the S8M Project area. The presence of radio collared ewes enabled a sightability correction factor to be derived and applied to calculate confidence intervals around population estimates using the immigration/emigration joint hypergeometric estimator (IEJHE) in NOREMARK software. The project area is thought to include two populations, referred to as the Sentinel and Stone populations. Sightability varied between populations and censuses, but mean sightability was greatest in December at 83.5% compared to 71.9% in March. The IEJHE population estimate for the Sentinel was 627 (95% CI 532 - 781) sheep. The Stone population was estimated at 545 (95% CI 475 - 648) sheep. Lamb to ewe ratios for all sheep enumerated in the Sentinel and Stone populations were 0.67 and 0.73 respectively in December and 0.64 and 0.51 in March. Density ≥1,400 m in the Sentinel population (0.64 sheep/km^2) was approximately one-half that of the Stone population (1.38 sheep/km^2) in December and 0.62 sheep/km^2 and 1.00 sheep/km^2 respectively in March. A greater total number of sheep and a greater proportion of marked sheep observed in December suggest that conducting a population survey during the end stage of the rut while sheep are congregated in high elevation alpine ranges may be the best option to obtain a more precise total population estimate, especially if little is known about the population age-sex structure or if the marked sample population is sexually biased.

Key words: Census, *Ovis dalli stonei*, population demographics, Stone's sheep.

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Formally established in 2004, the Sulphur / 8 Mile (S8M) Stone's Sheep Project is a multi-stakeholder collaborative initiative focused on researching Stone's sheep (*Ovis dalli stonei*) ecology in the S8M area of northern British Columbia (BC), with a specific emphasis on evaluating the potential for resource development impacts on wild mountain sheep populations (Churchill 2005). Stone's sheep, considered to be an important species to hunters, naturalists and special interest groups, are of particular significance in the S8M Project area, and as such are being given special consideration in the S8M oil and gas pre-tenure plan (PTP), a planning process which is mandated under the Muskwa-Kechika Management Area (M-KMA) Act for areas which have high resource development potential (MSRM 2004). One of the primary objectives of the S8M Project was to assess Stone's sheep population size, demographics, and stability, to provide a baseline for PTP management direction. The BC Ministry of Environment (MoE) conducted aerial sheep inventories in the project area in 1977 and 2004, without the benefit of marked sheep to assess sightability and calculate confidence intervals around population estimates. In 2005 and 2006, ewes were radio-collared to obtain habitat use data and assess levels and causes of sheep mortality (Churchill 2005). A population inventory was planned for winter 2006/2007, to assess Stone's sheep distribution and demographic structure and trends, and to assess the benefit from the presence of radio-collars to calculate a sightability correction factor (SCF) and population estimate. Initially, a single inventory was planned and timed for the latter stages of the rut in late November – early December (Nichols 1978) to maximize the potential to enumerate rams, which may not be in the census area at other times of the year, but congregate with ewe groups during this time. Maximizing the potential to observe rams was a priority because males were not represented in the radio-collared sample population. The objectives were to:

- Design and implement a census methodology that is repeatable in the S8M project area and can be applied in other regions that support Stone's sheep;
- Obtain a total count of Stone's sheep in the census area, recording number of sheep, group sizes, age/sex classification, distribution, and habitat characteristics;
- Determine an SCF, population estimate and confidence intervals using sightability and distribution of radio-collared sheep;
- Map the distribution of all sheep sighted;
- Estimate lamb survival to early winter and compare this estimate to pregnancy rate of ewes marked and sampled in March 2006;
- Record number and distribution of competing ungulates and predators observed in the census area.

In March 2007, MoE conducted Stone's sheep inventories throughout the BC's North Peace Region, without the benefit of marked animals to calculate a sightability correction factor and derive a corrected Stone's sheep population estimate. To provide confidence estimates for their survey results, a second census was conducted concurrently in the S8M project area. The March 2007 late winter census enabled us to:

- Determine a SCF that can be applied to late winter Stone's sheep inventory results;
- Incorporate census results into a repeated count analysis to improve confidence of the S8M population estimate;
- Compare early and late winter distribution and demographics;
- Compare the efficacy of a rut census in December to those typically conducted in late winter-early spring (MSRM 2002).

Study Area

The S8M Stone's Sheep Project area (Figure 1) is centered about 150 km west-northwest of Fort Nelson, BC, Canada and is located within the M-KMA. The project area land base is approximately 4237 km^2 and encompasses the Sulphur / 8 Mile, Toad River Corridor, Toad River Hot Springs and Stone Mountain Resource Management Zones (RMZ) defined by the Fort Nelson Land and Resource Management Plan (MSRM 1997), and most of BC WMU 7-54. The project area is bounded by the Alaska Highway, Liard River Corridor, and the

S8M PTP boundary. The PTP areas resulted from an interest of industry to explore and develop the area, and consultation with public advisory groups. The outcome of this process led to the creation of a low elevation and high elevation zone in the eastern portion of the project area. The low elevation zone is not considered high value habitat for Stone's sheep and has been approved for the sale of oil and gas tenures. Tenure sales have been deferred in the high elevation zone, which has been identified to contain high value habitat, to allow for Stone's sheep research and management direction to mitigate the impacts of industrial activity on sheep.

The northern extent of the Rocky Mountains is bounded by the Liard River Corridor, and the transition to the boreal plateau occurs to the east, fostering unique land formations and diverse habitat types. Much of the area was covered by the Laurentide ice sheet during the Wisconsinian ice age and is responsible for giving the area its unique landform morphology (Millot *et al.* 2003). Deciduous and coniferous forest comprises the majority of vegetation cover. Biogeoclimatic zones in the project area are Alpine Tundra (AT), Spruce-Willow-Birch (SWB and SWBmk) and Boreal White and Black Spruce (BWBSmw1 and BWBSmw2) (Meidinger and Pojar 1991). Climatic normals at Muncho Lake from 1971-2000, obtained from Environment Canada (http://www.climate.weatheroffice.ec.gc.ca) indicate that the area has a dry climate with an average annual precipitation of 496 mm and 106 frost free days. From November through to February, the average temperature is -18°C and from June through August the average temperature is 15°C. The temperature in summer often exceeds 30°C and in winter it can fall to -40°C.

Known internationally for its exceptional wildlife and wilderness values, much of the area is undeveloped, with motorized vehicle access limited to routes designated by the M-KMA Act. The protected areas adjacent to the project area have international significance due, in part, to the diversity of wildlife that includes wolf (*Canis lupus*), grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), moose (*Alces alces)*, Rocky Mountain elk (*Cervus elaphus*), deer (O*docoileus spp.)*, caribou (*Rangifer tarandus*), mountain goats (*Oreamnos americanus*), and Stone's sheep.

Because GPS collar and radiotelemetry data suggest that ewes belong to two subpopulations separated by the Toad River, we divided the S8M Project area into 2 subunits. One encompasses the Sentinel Mountain Range and is dominated by steep, rugged, alpine. This area extends northwest of the Toad River, and is hereafter referred to as the Sentinel population. The other subunit encompasses the less imposing Stone Mountain Range characterized by rounded peaks and increased vegetation cover at upper elevations. This area is southeast of the Toad River, hereafter referred to as the Stone population.

Methods

Capture and Radiocollaring

In March 2005 and 2006, 105 ewes >1 yr old were radiocollared in the project area. Sheep were captured by net-gunning from a Bell 206B helicopter, and fitted with either a motion-sensitive Very High Frequency (VHF) radiocollar or a Global Positioning System (GPS) collar with VHF transmitter. Progesterone levels from blood sera samples taken during March 2006 and March 2007 ewe captures were analyzed by the University of Saskatchewan Wildlife Health Centre. Serum progesterone levels >2 ng/ml indicated pregnancy.

Census Area Delineation

We stratified the project area according to ecosystem descriptions in Meidinger and Pojar (1991) who suggest that, although variable, alpine typically begins at an elevation of 1,400 m in north-eastern BC. We then correlated GPS location data from 9 collared ewes in our sample population with elevation, to discern if sheep were likely occupying open alpine habitats during the proposed time of the census. The census included all areas ≥1,400 m (approximate tree line) within the bounds of the S8M Project area (Table 1). The census area was mapped a priori using Geographic Information System (GIS) software to query Digital Elevation Model (DEM) data and produce census polygons for all areas ≥1,400 m.

Census Protocols

Census methodology and data collection conformed to provincial Resource Inventory Standards Committee (RISC) protocols for aerial ungulate inventories (MSRM 2002). Field data forms used followed RISC standards as well (MELP 1998). A Bell 206B Jet Ranger helicopter, equipped with two Yagi-Uda 2-element antennas mounted on opposing sides of the skid assembly, was used for both surveys. The crew consisted of a pilot, habitat/activity recorder, enumerator, and a navigator. The crew sat in the same seating arrangement in the aircraft throughout the census. All crew members actively participated in locating animals. The navigator employed blind telemetry (other members of the crew could not hear the radio collar VHF beacon) throughout the censuses to calculate sightability. If marked sheep were not observed, but heard by the navigator, the search for new animals was temporarily suspended at a natural break and the marked sheep were located using radiotelemetry.

Whenever possible, searches for animals began at 1,400 m elevation and, if necessary, subsequent passes were made increasing in elevation until the crew was confident the area was sufficiently searched. Tracks in snow, deemed relatively fresh, were followed as well. Although the focal species was Stone's sheep, all animals sighted were recorded and geo-referenced during the censuses to provide some insight on inter-specific competition on winter ranges within the S8M Project area. The total number of each group was recorded first then each crew member was assigned a specific age class or sex to enumerate. Ram age classifications followed Geist (1971), grouped by degree of horn curl in relation to the bridge of the nose as class I (¼ curl), class II (½ curl), class III (¾ curl) and class IV (full curl). Individual tallies were then compiled by the enumerator.

Real-time flight tracking (MNDNR 2000) was utilized in concert with a GIS platform (ESRI 1999) at all times during the census to map flight lines. An on-board computer displayed the helicopter location relative to the census polygons. Additional GIS coverages, such as local hydrology and roads, complimented the census polygons to aid the navigator and pilot during flight by providing a visual reference of landscape features. The rationale for this was three-fold:

- To provide accurate reference points that allowed the census crew to determine if an area was surveyed previously and provide an opportunity to end the survey at natural breaks of contiguous areas. Also, to find unsighted, marked sheep with telemetry or refuel the aircraft, and then resume with minimal risk of double counting animals;
- To establish a repeatable survey protocol;

- To allow us to calculate true survey effort by excluding ferry time between polygons and to re-fuel.

Data Analyses

We made assumptions that all marked and unmarked individuals within polygons were independently distributed and had an equivalent probability of being observed, and that no errors were made differentiating a marked and unmarked individual. We used NOREMARK software (White 1996), which incorporates a joint hypergeometric maximum likelihood estimator for repeated counts (Bartmann *et al.* 1987) with an extension to account for immigration and/or emigration (IEJHE) of sheep to/from the census polygons (Neal *et al.* 1993), to calculate a population estimate for each sub-population with 95% confidence intervals using the survey data from December 2006 and March 2007. The IEJHE input data is based on observations within the census polygons but incorporates the proportion of collared sheep outside the polygons and the minimum number sighted to derive an estimate of Sentinel and Stone ewe populations.

The IEJHE was used to calculate the population estimate for ewes only. We accounted for sexual bias of the marked sample population to estimate total lamb, yearling, and ram numbers by multiplying the proportion of lambs, yearlings, and rams to ewes in December by our derived population estimate of ewes for each population. We used the December data for all elevations to derive the estimates for lambs, yearlings, and rams because the number of ewes sighted did not differ between censuses, but fewer rams were observed in March. Sheep observed incidentally or by radiotelemetry at elevations below 1,400 m were included in the lower limit population estimates but censored out for sightability correction.

Relative group composition and mean group size of each population were calculated as well. Groups were classified as being either a ram, ewe, mixed, or nursery group. Nursery groups were defined as ewes with lambs, yearlings, and class I rams while mixed groups contained at least one class II or older ram. The proportion of lambs to ewes observed within each population was calculated for both December and March using observations from all elevations.

True survey effort for each census was calculated using flight line data to determine only the time spent actively searching for sheep and excluded ferry time to refuel or search for sheep with radiotelemetry. Density calculations were derived based on the total area of ≥1,400 m census polygons within each population sub-unit. Slope, aspect, and elevation of Stone's sheep within census polygons were derived by plotting animal locations on a DEM grid and employing an Avenue script to populate the point file attribute table. After confirming assumptions of normality, differences in mean slope, aspect, and elevation utilized by sheep between populations and censuses were tested for significance using analysis of variance (ANOVA). Mean group size was calculated for the Sentinel and Stone populations. A Student's *t*-test was used to determine if there were differences in mean group size among populations and censuses. Mean values are reported ± Standard Error (SE). All tests of significance were measured against the 95% confidence interval (α=0.05).

Results

Survey Conditions

Censuses were conducted on Nov. 22-23 and Dec. 9-16, 2006 and Mar. 16-23, 2007. Very cold ambient air temperatures (< -25 °C) required us to terminate the census temporarily on Nov. 24, 2006 and resume on Dec. 9, 2006. Areas previously searched that were spatially isolated, where the likelihood of animals emigrating or immigrating out of the area was low, were not resurveyed. Contiguous areas where there was increased likelihood of double counting were resurveyed in their entirety. With the exception of the cold temperatures in November 2006, weather conditions were generally favourable during both censuses. Frequent light snowfall overnight cleared in the morning allowing for good visibility. Strong winds made flying difficult at times but wind events were short lived and did not significantly hamper census activities.

Stone's Sheep Demography

Population size and structure - The total number of Stone's sheep counted within the S8M Project area in December 2006 was 939 and 875 in March 2007. True survey effort was 2.61 min/km^2 in December and 3.03 min/km^2 in March, and covered all census polygons. Sightability of marked ewes varied between populations and censuses (Table 2). Overall sightability was greatest in December at 83.5% compared to 71.9% in March. The IEJHE population estimate for adult ewes in the Sentinel was 224 (95% CI 190-279) and for the Stone was 202 (95% CI 176-240; Table 2). The Sentinel population was estimated at 150 lambs, 43 yearlings, 181 rams, and 29 unclassified for a total estimate of 627 (95% CI 532-781) sheep (Figure 2a). The Stone population estimates were 147 lambs, 26 yearlings, 156 rams, and 14 unclassified for a total population estimate of 545 (95% CI 475-648) sheep (Figure 2b).

Results of progesterone level analysis from blood samples collected during March 2006 captures indicate a mean pregnancy rate of 88.2 ± 0.7% among marked Stone's sheep ewes (*n* = 76). Pregnancy rates in the Sentinel and Stone populations were 88.9% (*n* = 36) and 87.5% (*n* = 40) respectively. Assuming all lambs were brought to full term, we observed an overall neonate to 6 mths survival rate of 79% and 65% survival to 9 mths (Table 3). Lamb survival to 6 mths was similar between Sentinel and Stone populations but differed between populations in March. There were similar lamb to ewe ratios between collared and uncollared ewes. We calculated lamb to collared ewe ratios at all elevations and populations at 0.70 in December and 0.60 in March. Overall ratios of lambs to uncollared ewes were 0.72 and 0.61 in December and March respectively.

Distribution, group sizes, and density - Large-scale distribution of groups did not appear to vary notably between censuses. However, we observed a 21% decline (*n* = 44) in the number of rams sighted within all census polygons between December and March. This decrease was most evident with respect to class II and III rams in the Stone population, with 59% (*n* = 48) fewer observed above tree line in March compared to December. The mean group size of Stone's sheep observed within the census polygons varied between censuses (Table 4). Mean group size was larger in the Stone population than the Sentinel population in March ($F_{1,\ 113}$ = 5.27, P = 0.024). Relative group composition was similar with only mixed and nursery groups changing notably from December to March (Table 4). In both December and March, 80% of all groups located at <1,400 m elevation were within 200 m of census polygon boundaries. Stone's sheep density within the census polygons was similar in the Sentinel population but differed in the Stone population between December and March. The Sentinel population density was 0.64 sheep/km^2 in December and 0.62 sheep/km^2 in March. Stone's sheep density in the Stone population was 1.38 sheep/km^2 and

1.00 sheep/km^2 respectively. Mean sheep density within all census polygons was 1.01 ± 0.37sheep/ km^2 in December and 0.81 ± 0.19 sheep/ km^2 in March.

Habitat associations **-** Mean slope, aspect, and elevation of Stone's sheep during December 2006 in the Sentinel and Stone populations were 32 ± 0.97 degrees, 189 ± 10.85 degrees, 1617 ± 9.47 m and 31 ± 1.15 degrees, 175 ± 13.27 degrees, and 1566 ± 12.33 m respectively. Mean elevation of sheep differed between populations in December ($F_{1, 163}$ = 7.40, P = 0.007). Mean slope, aspect and elevation occupied by sheep during March 2007 in the Sentinel and Stone populations were 32 ± 1.03 degrees, 196 ± 10.75 degrees, 1620 ± 15.78 m and 36 ± 1.45 degrees, 203 ± 9.60 degrees and 1536 ± 18.09 m, respectively. Mean slope ($F_{1, 113}$ = 6.79, P = 0.01) and elevation ($F_{1, 113}$ = 10.06, P = 0.002) differed between populations in March.

Discussion

Conducting two population censuses in a single winter provided an opportunity to establish a population estimate with a high level of confidence, and to assess the implications of early and late winter survey protocols for population estimation. The data suggest that there were approximately 1,200 sheep (minimum 939) in the S8M Project area in 2006/2007. By comparison, MWLAP (2004) conducted an aerial survey for Stone's sheep in the S8M Project area in March 2004. This total count survey of suitable winter habitat reported 888 sheep were observed; 507 in the Sentinel and adjacent ranges west of the Toad River, and 381 in the Stone Mountain Range, southeast of the Toad River. MWLAP (2004) also reported results for a similar survey in 1977, which found 997 sheep total.

Data summaries presented by AXYS (2005) indicate that MWLAP's March 2004 classification included 419 (47%) ewes and class I rams, 149 (17%) lambs, 80 (9%) yearlings, and 240 (27%) rams. The reported lamb: ewe ratio was 0.36 ('ewes' included yearling and Class I rams) and the ram: ewe ratio was 0.57. This is comparable to the March 2007 classification of 875 sheep that included 399 (46%) ewes and class I rams, 200 (23%) lambs, 54 (6%) yearlings, and 193 (22%) rams observed in the project area (all elevations), for both populations combined.

The estimated pregnancy rate of 88% suggests good population productivity as pregnancy rates of 75 to 100% are considered typical for thinhorn sheep (Hoefs and Bayer 1983, Nichols and Bunnell 1999). Lamb: ewe ratios reported for mountain sheep ranged from 0.08-0.82 (Nichols 1978, Harper 1984, MoE 1985, Douglas and Leslie 1986, Wehausen et al. 1987, Hass 1989, Corbould 2001, Wood 2002, Walker et al. 2006). Our data suggest favourable recruitment in both populations within the S8M Project area as our ratios tend toward the upper range of these values. Recent studies of Stone's sheep in northern BC reported spring-summer lamb to ewe ratios of 0.82 (Walker et al. 2006), 0.27 (Wood 2002) and 0.30 (Corbould 2001). Demarchi and Hartwig (2004) note that summer lamb to ewe and yearling ratios of 0.30 - 0.40 are generally considered sufficient for population stability, assuming normal winter conditions. Given approximately 15% annual mortality rate of ewes (S8M Stone's Sheep Project, unpublished data) and assuming an equal sex ratio in lamb production, late winter lamb to ewe ratios ≥0.30 should be expected to support a stable or growing population.

The general distribution of sheep observed in December 2006 and March 2007 did not change across the study area.

With the exception of a decline in lamb to ewe ratios and the number of young rams in the Stone population, our age and sex classifications were also very consistent between the December and March censuses. This supports our assumption of geographic closure of wintering herds within the project area, and indicates good repeatability with respect to our census results.

Typically, aerial surveys of mountain sheep attempt to completely cover an acceptable number of survey units or strata and strive to enumerate every sheep in these strata (Neal et al. 1993, Bodie et al. 1995, Udevitz et al. 2006). Survey effort reported from thinhorn sheep inventories in Alaska ranged from 0.30 - 1.34 min/km^2 using fixed-wing aircraft (Strickland et al. 1994, Udevitz et al. 2006). Our survey effort is similar to helicopter surveys of mountain sheep in Colorado (2.60 min/km^2) and mountain goats in northern BC, which occupy similar habitats to sheep (3.80 min/km^2; 3.1 min/km^2) (Neal et al. 1993, Poole et al. 2001, Hengeveld 2004). However, the detection rates reported were lower in all but one inventory cited than the means of both of our inventories.

It has been suggested that detectability of mountain sheep can be influenced by group size and composition, activity, habitat, weather, and the relative location of the animal to the aircraft in complex topography (Strickland et al. 1994, Bodie et al. 1995). We agree that larger group size increases sightability (Eberhardt et al. 1998, Udevitz et al. 2006) but only to a degree as large groups (>20) were much more difficult to enumerate and class than smaller groups and marks can easily be missed. We contend sightability was considerably reduced in the Sentinel population in March as sheep appeared to elicit a flight response to the helicopter less often in March than in December, and were dispersed within expansive, rugged alpine that enabled sheep to retreat for cover against the rocks and remain relatively motionless, effectively lowering their detectability to observers.

Our assumption that there was an equivalent probability of sighting all marked and unmarked individuals was likely a source of error. Given the gregarious nature of sheep, their tendency to site fidelity, the presence of more than one marked sheep in some groups, and that group characteristics can affect detection probabilities, it may be argued that sightability should based on the number of marked groups observed, rather than the number of marked individuals. Based on these assertions, we calculated sightability of marked ewes both as an individual and by groups during analyses. Our findings agree with those of Neal *et al.* (1993) that population estimates that use groups for calculations rather than by individuals results in an overestimation of the target population, especially if the population is large. As well, a decrease in confidence due to the reduced number of marks available for sightability correction emerges when calculating population estimates using marked groups rather than on marked individuals sighted.

Udevitz *et al*. (2006) reported a high mean detection rate (88%) of marked collars and stated that confidence in annual population estimates increased due to the number of marked sheep sighted and not due to refining estimates of detection probabilities. In some instances, marked ewes in the S8M area were not sighted in the open alpine during the surveys and were subsequently located outside of census polygons using telemetry, often using tree canopy near the polygon boundaries for refuge. However, due to the relatively large sample size and using proportions of sighted marks over both surveys, the reduction in precision of the estimate is likely small (Neal *et al.* 1993).

The results in relative group composition between surveys were somewhat surprising. As mountain sheep are typically sexually segregated throughout most of the year and interact only during courtship (Geist 1971, Seip 1983), we expected greater separation of ram and ewe/nursery groups in late winter. High ram to ewe ratios and similar relative group composition between surveys suggest we likely sighted most rams, and they appeared to be occupying the same ranges as ewes. The increase in mean group size coupled with the decrease in the number of groups in late winter may suggest limitations in optimal winter ranges within the project area (Shackleton *et al.* 1999). If limitations of optimal winter range exist, this appears more evident in the Stone population where late-winter group aggregation is more pronounced, and overall densities are approximately double that of Sentinel sheep. Over-winter lamb survival was lower in the Stone population than in the Sentinel population. This may suggest that there are density-related limitations of optimal winter habitat in the Stone population at elevations ≥1,400. Further, limited optimal winter range and higher density may cause sheep to utilize habitats that may increase the chance of predation or reduce nutritional resources, increasing winter mortality (Douglas and Leslie 1986, Wehausen et al. 1987, Festa-Bianchet 1988, Portier et al. 1998).

While the two populations appear to differ somewhat demographically with density potentially being the key factor, broad habitat associations were similar, with sheep favouring south-facing, moderate-steep slopes in winter. Differences in mean elevation may be due to the topography and elevation range between mountain ranges or snow depth as Stone's sheep may stop excavating for forage when snow depths exceed 30 cm (Seip and Bunnell 1985) or when snowpack conditions hinder forage efforts (Geist 1971). Habitat data for both December and March agree with that reported from other Stone's sheep studies where winter range typically consists of steep, south-facing cliffs (Wood 1995, Corbould 2001) and wind-blown alpine ridges (Backmeyer 1991). Use of these areas by competing species varied between censuses, with moose and elk potentially significant competitors in the eastern Stone area, particularly at elevations at or near tree line, and caribou more prevalent in the Sentinel area.

Management Implications

Results from both censuses indicate little use of the northern half of the S8M High Elevation Zone PTP area by Stone's sheep. Only one group of 4 sheep (including a radiocollared ewe) was observed during the December 2006 and March 2007 surveys. Both ewes and rams are known to use ranges in the southern half of the High Elevation Zone PTP area, south of the Toad River. Of particular interest with respect to our analyses is that we counted similar numbers of ewes, but less than half the number of 3-6 yr old (approx.) rams above tree line in this area in March compared to December. In the Sentinel Range, we counted about the same number of rams in December and March. This suggests that rams and ewes may differ in their use of the southern portion of the PTP area, with rams possibly using lower elevation habitats in late winter or moving to different ranges. Habitat use data collected with GPS collars on ewes and rams will be used to quantify habitat values, and help to identify the importance of the PTP area to Stone's sheep.

Because the oil and gas industry has significant interest in developing the area, the impetus to capture current, accurate demographic and distribution data on the sheep population residing within the

Sulphur/8 Mile Project area provided the rationale to conduct intensive inventories during the baseline phase. Designing a repeatable census methodology, utilizing on-board, real-time flight tracking with GIS and marked ewes for sightability correction, enabled an accurate population estimate. A greater total number of sheep and a greater proportion of marked sheep observed in December provided justification for using December ratios of ewes to lambs, yearlings, and rams to estimate total population size. As such, conducting a population survey during the end stage of the rut while sheep are congregated in high elevation alpine ranges may be the best option to obtain a more precise total population estimate, especially if little is known about the population's age-sex structure or the marked sample population is sexually biased.

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Tables

Table 1. Total area (km^2), census area (km^2; ≥1,400 m elevation) and elevation (metres above sea level) of the Sentinel and Stone subunits within the Sulphur / 8 Mile Stone's Sheep Project area, northern British Columbia.

Subunit	Census area	Total area	Elevation range
Sentinel	579	2460	450-2350
Stone	257	1777	450-2100
Total	836	4237	450-2350

Table 2. Mark-resight parameters for females marked with radiocollars in two Stone's sheep populations enumerated during the December 2006 and March 2007 censuses in the Sulphur/8 Mile Project area, northern British Columbia. The census polygons were limited to alpine areas (≥1,400 m elevation); sheep sighted at lower elevations (<1,400 m) were located incidentally or found by telemetry of radio-collared sheep. The total number of females was estimated using NOREMARK software for repeated counts, incorporating a joint hypergeometric maximum likelihood estimator with an extension to account for immigration and/or emigration (IEJHE) of sheep to/from the census polygons.

	Total marked	# marked in census area (% of total)	Marked seen (% sightability in census area)	Unmarked females sighted in census area	IEJHE estimate for total number of females (95% CI)
Sentinel					
December	32	24 (75.0)	21 (87.5)	110	224
March	32	29 (90.6)	17 (58.6)	117	(190 – 279)
Stone					
December	45	39 (86.7)	31 (79.5)	102	202
March	42	27 (64.3)	23 (85.2)	97	(176 – 240)

Table 3. Estimated Stone's sheep lamb survival to 6 and 9 months calculated using observed lamb to ewe ratios for the Sentinel and Stone populations in the Sulphur/8 Mile Project area, northern British Columbia. Pregnancy rates were estimated from blood progesterone levels of 76 adult ewes during March 2006 capture.

Date	Sentinel	Stone
Pregnancy rate	0.89	0.88
December 2006 census		
Lamb:ewe	0.67	0.73
Lamb survival to 6 mths	0.75	0.83
March 2007 census		
Lamb:ewe	0.64	0.51
Lamb survival to 9 mths	0.72	0.58
Overwinter lamb survival (Dec - Mar)	0.96	0.70

Table 4. Mean group size and relative group composition of Stone's sheep enumerated within the census polygons (≥1,400m) during the December 2006 and March 2007 censuses in the Sulphur/8 Mile Project area, northern British Columbia. Nursery groups were defined as ewes with lambs, yearlings and class I rams while mixed groups contained at least one class II or older ram.

Census date	# groups	Mean	Ewes	Mixed	Nursery	Rams	Unclassified
December							
Sentinel	93	3.98 ± 0.34	0.03	0.41	0.30	0.24	0.02
Stone	71	5.00 ± 0.47	0.04	0.54	0.21	0.21	0
Combined	164	4.42 ± 0.28	0.04	0.46	0.26	0.23	0.01
March							
Sentinel	78	4.64 ± 0.53	0.06	0.36	0.29	0.24	0.04
Stone	36	7.14 ± 1.12	0.05	0.28	0.44	0.22	0
Combined	114	5.43 ± 0.52	0.06	0.33	0.34	0.23	0.03

Figures

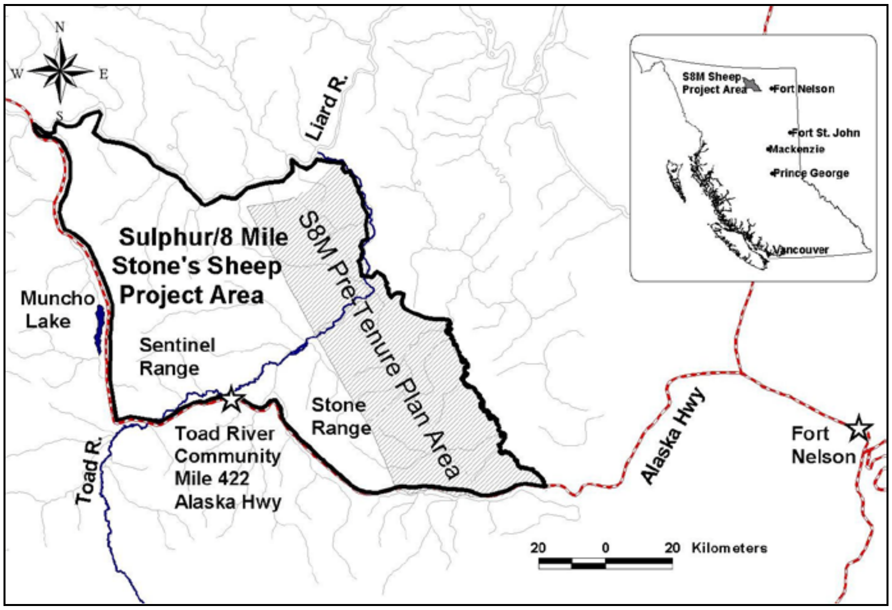

Fig. 1

Figure 1 Location of the Sulphur / 8 Mile (S8M) Stone's Sheep Project area in northern British Columbia, Canada. The Toad River divides the project area into the Sentinel (north) and Stone (south) subunits. Boundary of the S8M oil and gas pre-tenure plan area is shown.

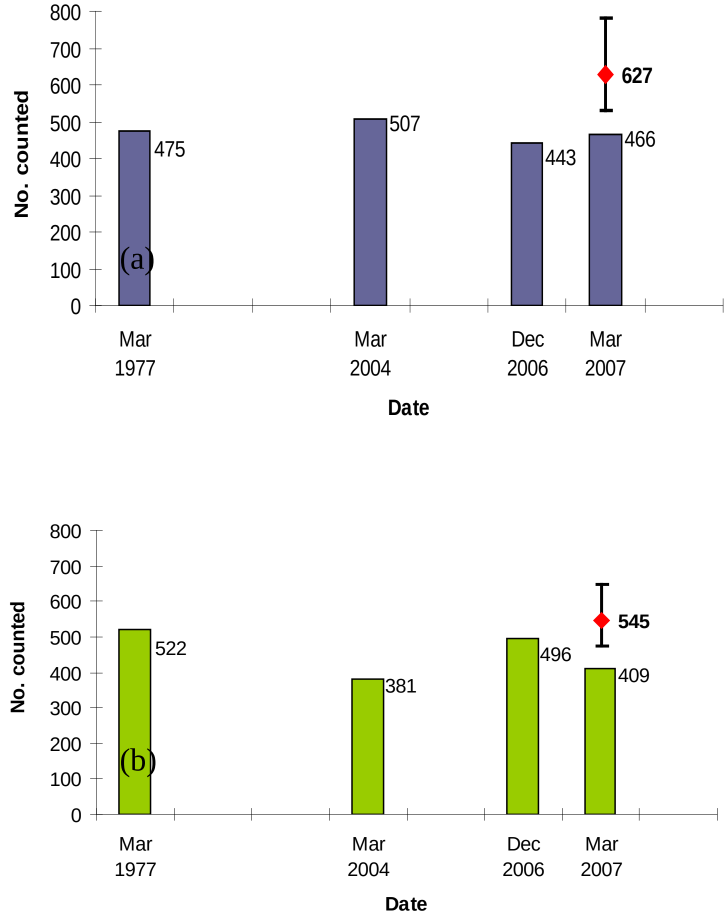

Figure 2. Winter 2006/2007 population estimates (red diamond) for the Sentinel (a) and Stone (b) populations with 95% confidence intervals, based on sightability of marked ewes and the total number of Stone's sheep observed in the project area. Using December 2006 and March 2007 survey results, ewe estimates were calculated using NOREMARK software for repeated counts incorporating a joint hypergeometric maximum likelihood estimator with an extension to account for immigration and emigration from census polygons. Lamb, yearling and ram estimates were calculated using the proportion to ewes counted in December. March 1977 and 2004 counts are from inventories conducted by MoE without the benefit of marked sheep (MWLAP 2004).