Biennial Symposium Northern Wild Sheep and Goat Council 12:1-10.

IDENTIFICATION OF BIGHORN SHEEP MIGRATION CORRIDORS USING GPS TELEMETRY SYSTEMS

SUSAN L. LEMKE, Ursus Ecological Consulting, 2347 Omineca Drive, Kamloops, B.C. V2E 1S9
DOUGLAS N. JURY, British Columbia Ministry of Environment, Lands and Parks, Wildlife Management Program, 1259 Dalhousie Drive, Kamloops, B.C. V2C 5Z5

Abstract: Employing Global Positioning System (GPS) telemetry collars, an ongoing 3-year study of the Fraser River/Marble Range California bighorn sheep population is 1) evaluating the utility of a GPS animal location system in defining the movement corridors of large ungulates, and 2) identifying migration routes of the local sheep herd and determining migration timing between seasonal ranges. The importance of historically known summer habitats in the Marble Range mountains has been confirmed, and 2 distinct migration routes have been defined, based on satellite location fixes collected on 15-minute intervals. Preliminary data suggest that, once initiated, animals navigate migration corridors without delay, as indicated by rates of travel recorded for an adult ram (0 = 2.64 ± 0.18 km/hour) and an adult ewe (0 = 1.60 ± 0.09 km/hour).

Development in the Marble Range region of the southern interior of British Columbia may negatively impact the integrity of important summer range and migration corridors of the local bighorn population. Continuing work is expanding knowledge of seasonal habitat use patterns in the area and identifying additional migration routes. This information will ultimately be incorporated into land use guidelines sensitive to the requirements of the local bighorn population.

Key words: bighorn sheep, *Ovis canadensis californiana*, migration corridors, British Columbia, global positioning system.

The Fraser River (East) California bighorn sheep (*Ovis canadensis californiana*) population of the southern interior of British Columbia is comprised of both migratory and non-migratory sub-populations. Non-migratory animals spend the majority of their lives within sight of the Fraser River. Migratory individuals, by contrast, travel seasonally between low elevation slopes and benches on the eastern bank of the Fraser River, and high elevation alpine meadow habitats in the Marble Range mountains to the east. Historically, the migratory sub-population, comprising up to 50% of the herd, moved between the Fraser River and the Marble Range in many locations; however, over the past 4 decades, the northern migration routes have been abandoned, and the southern corridors now exclusively support seasonal movements (D. Eyer, Clinton and District Outdoor Sportsmen Association, personal communication). Evidence suggests that 25% of the herd currently exhibits migratory behaviour. Several factors have been implicated in the shift to the southern routes, including rural residential development, power line construction, timber harvesting activities and the loss of older sheep that used these routes. The result has been an increasing number of sheep remaining on the Fraser River winter range year-round. The higher density of animals on this range has degraded forage quality, and has been implicated in a recent lungworm-induced pneumonia die-off (B.C. Environment, unpublished data). A significant reduction in lamb recruitment resulted in an increasing population of approximately 400 animals being reduced by 40-50% over a 3-year period (1990-1993). Annual aerial surveys throughout the mid-1990s indicated that lamb recruitment was still at low levels (B.C. Environment, unpublished data). A recovery in lamb recruitment was evident beginning in 1997, although population levels are not responding yet.

Preserving the remaining southern migration routes will permit migratory individuals to take advantage of high quality summer forage in alpine areas and, subsequently, may reduce the likelihood of future die-off events by decreasing population densities on over-exploited low elevation habitats. Two provincial parks, Marble Range and Edge Hills, have recently been established in the region, protecting valuable sheep habitat. However, important summer range and portions of the suspected southern migratory corridors lie within an area held in mining claims, which were excluded from the parks. Timber harvesting and the installation of an electrical transmission line have altered the landscape in the valley situated between the Marble Range and the Edge Hills, although the impact of these changes on the migratory behaviour of this herd is presently unknown. Risenhoover and Bailey (1985) reported that mountain sheep avoided dense, tall vegetation, such as Douglas fir stands; preferred habitats included open areas where acceptable forage densities and visibility (i.e. predator detection) were greater. Radio telemetry work on the Churn Creek herd of British Columbia also suggested that animals were travelling quickly along the forested portions of an identified migration route (Keystone Wildlife Research 1998).

This study was developed to 1) evaluate the utility of Global Positioning System (GPS) telemetry systems in defining movement corridors for large ungulates and 2) identify and accurately map the remaining bighorn sheep migration corridors in the Fraser River/Marble Range area. The project was initiated in 1998, and is scheduled to continue through mid-2001.

STUDY AREA

The study area encompasses approximately 500 km^2 east of the Fraser River, 200 km northeast of the city of Vancouver, B.C. Elevations range from approximately 250 m on the Fraser River in the west to 2250 m in the Marble Range mountains to the east (Fig. 1).

High elevation alpine meadows, where sedges (*Carex* spp.), grasses and forbs predominate, and scattered stands of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), are representative of bighorn sheep summer habitat in the Marble Range mountains. The western margin of the range drops precipitously through limestone cliffs to the Kostering Creek valley. The area experiences cool short growing seasons, while winters are long and cold. Mean annual precipitation is 400-500 mm, most of which (50-70%) falls as snow (Meidinger and Pojar 1991). Sheep winter range on the Fraser River includes the western slopes of the Edge Hills, where open stands of Douglas fir (*Pseudotsuga menziesii*) and Ponderosa pine (*Pinus ponderosa*) predominate. The sagebrush (*Artemisia tridentata*)/bunchgrass (*Elymus spicatus*) benches above the Fraser River (450 m in elevation) are also utilized. This area is characterized by hot, dry summers, with substantial growing season moisture deficits common. Winters are cool and 20-50% of mean annual precipitation (300 mm) falls as snow.

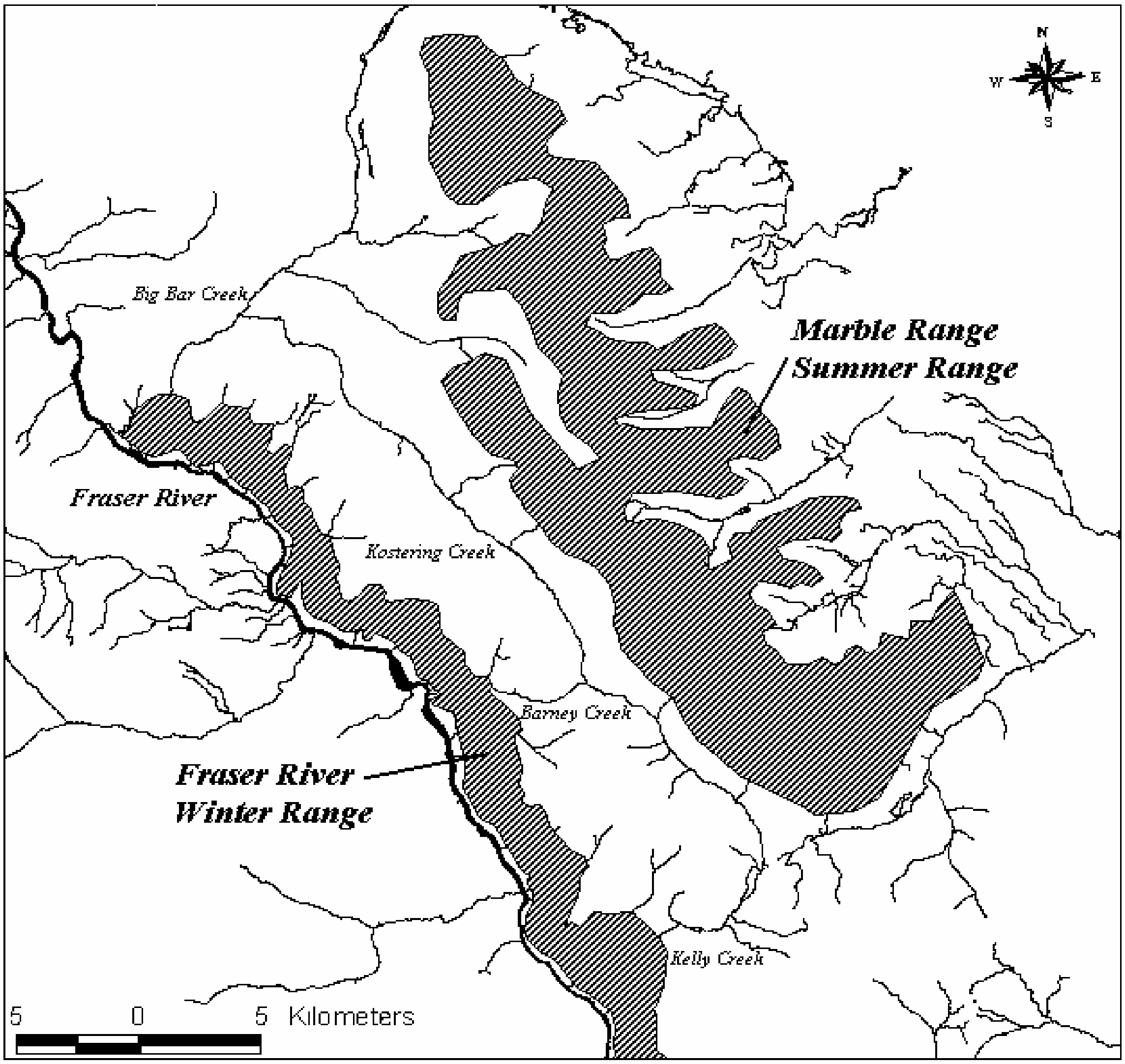

Fig. 1. Marble Range bighorn sheep seasonal ranges

METHODS

Animal Capture and Collaring

Animals were captured in late summer, prior to expected migration from summer to winter range. Sheep were captured via helicopter netgunning using a Bell 206B JetRanger. On the ground, sheep were blindfolded and hobbled. Once the animal was restrained, an Advanced Telemetry Systems (ATS, Isanti, Minnesota) Global Positioning System (GPS) collar, equipped with a VHF transmitter and a remotely activated release mechanism, was readied for deployment. The units weighed 950 g, and were programmed to fix their location every 15 minutes. Battery life was calculated at 40-50 days at this fix interval. The collar's GPS receiver was initialized according to manufacturer's instructions (ATS 1998), during which time the animal's neck measurement was taken, age was determined (based on horn annuli), and an assessment of general health was completed. Upon successful completion of the initialization sequence, the collar was placed on the animal, the hobbles and blindfold removed, and the animal released. Collar functioning was reconfirmed using a Telonics TR-2 telemetry receiver. Lotek LMRT-3 VHF telemetry collars (Lotek Engineering, Newmarket, Ontario) were available, to be used in cases of multiple-animal captures.

Two animals, a 4-year-old ram (Ram #128-1) and a 5-year-old ewe (Ewe #129), were captured on summer range and fitted with GPS collars on 19 August 1999. A second ram captured with the first received a VHF collar. The GPS collar was carried by the ram for 20 days before the unit was released on 7 September 1999, to confirm collar functioning. The collar on the ewe was released after 39 days (26 September 1999).

A 7-year-old ram (Ram #128-2) was captured on the Marble Range summer habitat and fitted with a GPS collar on 2 November 1999. The unit remained on the animal for 38 days, before being released on 9 December 1999.

Monitoring and Collar Retrieval

Approximately 40 days after collar deployment, a monitoring flight was undertaken, and the location of the collared animal(s) determined. If the animal had traveled between its seasonal ranges, the ATS triggering transmitter unit was employed to activate the release mechanism on the collar. Once released from the animal, the collar was located and retrieved.

Data Analyses

Offloading of data from the collar GPS receivers was accomplished using a PC-based system running ATS Collar (Version 13) software. The data collected and stored in the collars' on-board memory included the date, time, horizontal position, elevation, fix type [2- or 3-dimensional (2D or 3D)], satellite information, positional dilution of precision (PDOP) and the time required to obtain a fix during each specified interval. Data required for differential correction were not collected in the current ATS collar model.

Location data were imported into ArcView GIS Version 3.0a (Environmental Systems Research Institute, Redlands, California) for plotting and analyses. All calculated distances are linear.

RESULTS

Movements and Migration Corridors

The GPS collar carried by Ram #128-1 recorded 862 fixes; due to an oversight in collar programming, this unit collected locations once every 30 minutes. Eighty-one percent of fixes were 3D. The mean PDOP value for locations was 3.56. This animal remained on summer range throughout the collar trial. He moved about near the capture site for 0.5 days, and then moved approximately 9 km south, where he remained for another 0.5 days. He then traveled an additional 6 km towards the southern end of the Marble Range, where he remained until the collar was released (Fig. 2). Major movements were initiated during the early morning hours (0530 – 0700 hrs) and completed by mid-afternoon (1600 hrs).

The second collar (Ewe #129) collected 3,154 location fixes, with 82% recorded as 3D. The mean PDOP was 3.68. This animal moved from the Marble Range to the Fraser River winter range on 3 September, and then traveled back to summer habitat on 16 September, where she remained until the collar was released on 26 September. The collar's GPS receiver did not record the animal's locations on the route from the mountains to the Fraser River; however, the return trip in mid-September was successfully fixed (Fig. 3). This corridor covered a distance of approximately 8 km, which the animal traveled in 4 hours and 45 minutes between 1214 and 1700 hrs. Once initiated, movement between seasonal ranges progressed steadily, at a mean rate of travel of 1.60 ± 0.09 km/hour. The collar on Ram #128-2 recorded 3,070 locations, 82% of which were 3D. Mean PDOP was 3.43. The animal's migration movement from the Marble Range to the Fraser River occurred on 10 November during the early afternoon hours (1248 – 1603 hrs; 3 hrs 14 min) and covered approximately 8 km (Fig. 4). Mean movement rate through the corridor was 2.46 ± 0.18 km/hour.

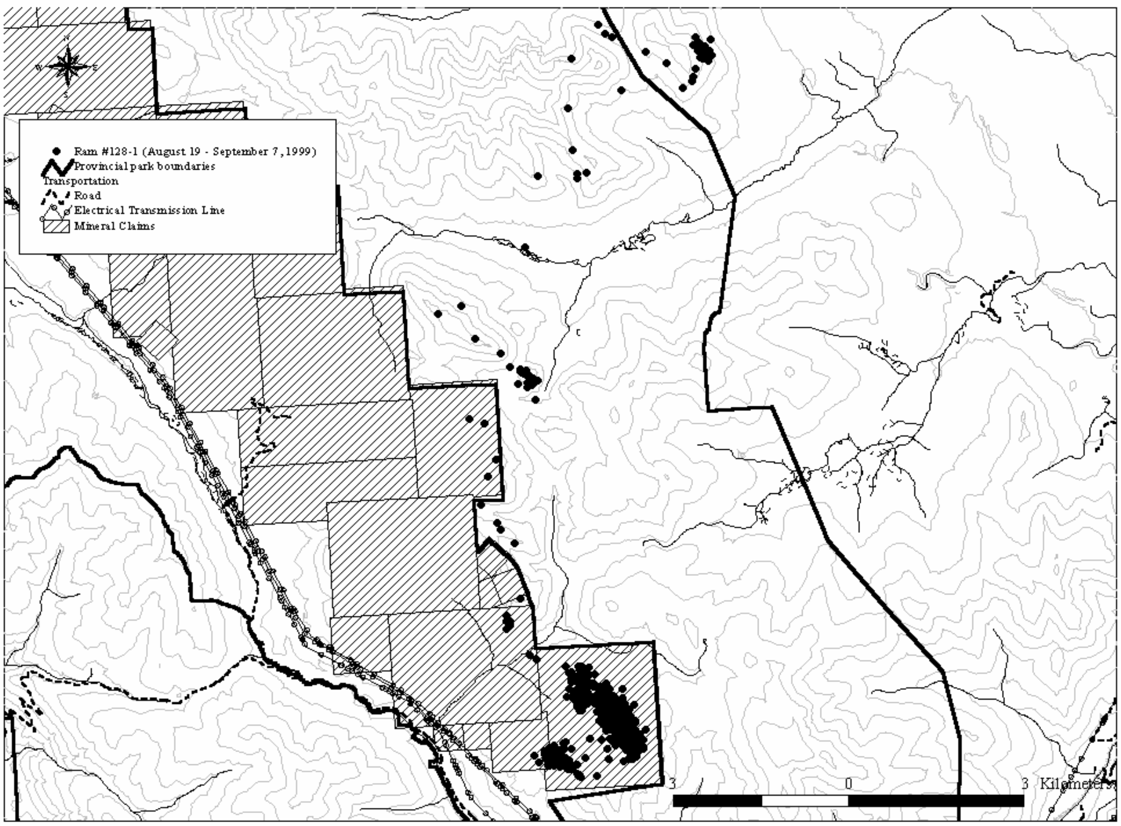

Fig. 2. GPS location data for Ram #128-1: 19 August September 1999

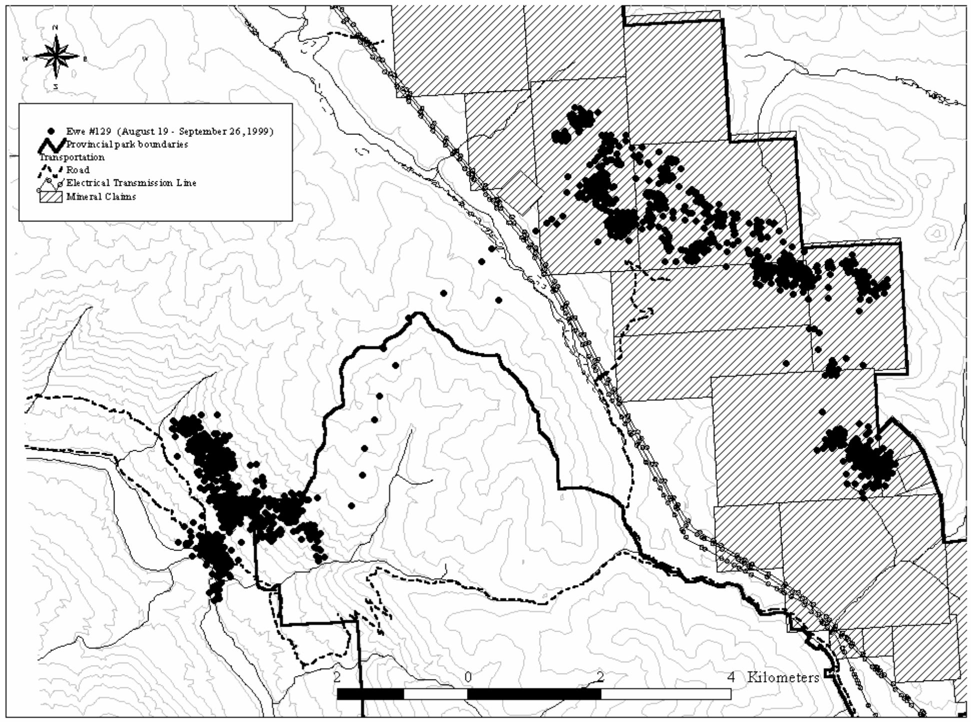

Fig. 3. GPS location data for Ewe #129: 19 August – 26 September 1999

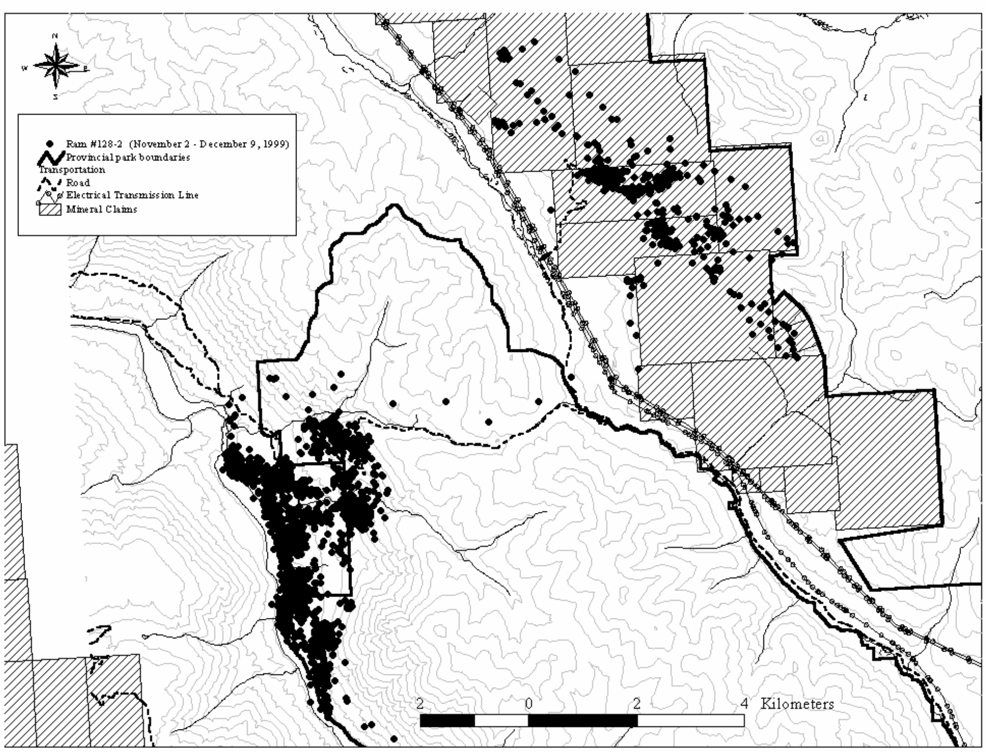

Fig. 4. GPS location data for Ram #128-2: 2 November – 9 December 1999

DISCUSSION

GPS Utility

Preliminary data from GPS-collared bighorn sheep of the Fraser River/Marble Range herd indicate that GPS telemetry systems can be an extremely valuable tool in identifying important movement and migration routes for large ungulates. The advantages of GPS collars versus VHF units in wildlife research are many, and generally outweigh the higher cost, variable reliability and increased complexity of data handling required (Kinley 1998). For the purposes of the current project, where the focus was a well-defined time window (i.e. migration), the ability to program these units for short intervals between fix attempts (i.e. every 15 minutes), maximizes data collected, ultimately providing a precise definition of travel routes. GPS systems are also more likely to record use of special habitat features, such as mineral licks, which are visited infrequently. VHF telemetry monitoring is restricted to daylight hours and conditions optimal for flying, whereas GPS systems are less biased with respect to time of day and weather conditions. GPS collar data, however, may be more biased relative to habitat type and topography than is VHF data, because of signal transmission interference (Rempel et al. 1995, Moen et al. 1996). The disturbance associated with aerial telemetry monitoring, which may result in animals altering their movements and habitat selection patterns (Poole and Heard 1998), is eliminated with the use of data retention GPS collars.

The high percentage of 3D versus 2D fixes obtained in this study is significant compared to other recent studies utilizing GPS collars on mountain ungulates. Poole (1998) reported 30% and 67% 3D fixes, respectively, using 2 ATS prototype collars on mountain goats in east-central British Columbia. An ongoing mountain caribou study being conducted in the Wells Gray region of B.C. reported 38% 3D fixes (Norquay 1999). Fix accuracy is improved considerably when a 3D fix (i.e. 4 or more satellites available) is obtained (Moen et al. 1997, Rempel and Rodgers 1997). Indeed, Norquay (1999) suggested that all non-differentially corrected 2D fixes and differentially corrected 2D fixes with PDOP values greater than 4.5 should be rejected, as much of the error associated with these data (resulting from poor satellite geometry) are larger and more difficult to assess than that for 3D data. Based on a review of recent literature, a mean error of 60-80 m (95% within 250 m) may be expected with 2D non-differentially corrected fixes (Timberland Consultants, unpublished data). The collars used in the current study did not permit differential correction of satellite locations; however, the comparatively small percentage of 2D fixes, low mean PDOP values associated with these fixes (3.47), and the level of precision deemed necessary to evaluate seasonal habitat use and delineate migration corridors, i.e. 300-500 m width proposed, justified retaining all location points for plotting. The recent removal of selective availability error from GPS receivers (1 May 2000) has rendered differential correction processes obsolete. Units deployed subsequent to this date are expected to obtain location fixes accurate to within 10 m.

Technical Difficulties

Several technical difficulties were encountered during these initial stages of the project, all of which were diagnosed and corrected. The first remote release of a GPS collar in September was accomplished without difficulty; however, immediately afterwards, attempts to release the second collar failed. An electronic malfunction associated with the triggering transmitter's power source was diagnosed and repaired by ATS. Subsequent release operations were accomplished without incident.

The failure of the ewe's GPS unit to record locations through a 2.5-hour time block during her movement between the Marble Range and the Fraser River on 3 September 1999 is inexplicable. Data sets exhibit gaps of 30-45 minutes, where an insufficient number of satellites were available to obtain a fix; however, gaps of 1 hour were infrequent and greater than 1 hour, rare. Vegetation (i.e. canopy cover) and topographic relief both affect satellite acquisition through signal interference. Although receiver malfunction cannot be ruled out, the incidence of data gaps of varying duration indicate that features of the habitat are the most likely explanation for the incomplete location data.

Seasonal Range and Migration Corridors

Data available to date suggest that the rugged southwestern extent of the Marble Range, west of the Marble Range Provincial Park boundary and within the mining claims, remains the preferred summer habitat of the migratory Fraser River sheep herd. The 1999 summer range locations for each of the 3 GPS collared animals concentrated in this sector. The lack of use of range within the park boundary may be a result of similar habitat use patterns of the small sample of collared animals, or may relate to some yet unrecognized attribute of the habitat in this particular area.

The migration routes recorded thus far have confirmed local knowledge of bighorn habitat use in some instances, and provided unexpected results in others. For example, the ram's migration route through the Edge Hills region has been known to locals for many years; however, the portion of the route through the Kostering Creek valley was new information to both locals and biologists. The timing of the migration in this case (10 November) was also surprising: migration out of the Marble Range was thought to be complete by the end of October.

The ewe's unexpected migration took her approximately 1 km north of the northernmost expected route. Knowledgeable residents were unaware that sheep used this area north of Barney Creek.

GPS location data have provided a graphic illustration of the migration behaviour of bighorn sheep of the Fraser River/Marble Range herd. Once migratory movements between seasonal ranges are initiated, it appears that the animals do not delay en route. Regardless of route location, migrating animals must cross a wide electrical transmission line right-of-way and a major road. In some locations, human habitation and large cutblocks must also be negotiated. The effect of these landscape features on migratory behaviour is presently unknown. Future work will address this issue through spatial analyses using digital orthophotograph coverage in a GIS environment. Location data collected in 2000 and 2001 may define currently unknown routes will further understanding of seasonal habitat use patterns and existing movement corridors.

MANAGEMENT CONSIDERATIONS

The die-off that seriously impacted the Fraser River bighorn population in the early 1990s has left the population at its lowest numbers in 20 years. Although the Marble Range sub-population was not affected to the same extent as the more northern sub-herd, the pneumonia-related lamb mortality was significant. Based on aerial survey data, this population is currently at 20% of the late 1980s estimate (B.C. Environment, unpublished data). Recent surveys indicate that lamb recruitment is rebounding, although total numbers do not appear to be increasing yet. The significance of important seasonal ranges and movement corridors, therefore, cannot be overstated. The protection of the remaining summer range in the southern Marble Range and the associated migration routes should aid in the recovery of the population to historic levels.

CONTINUING WORK

Currently, 2 GPS collars are deployed on rams captured on the Fraser River winter range. Following migration to the Marble Range in early to mid-June 2000, the collars will be released and the data offloaded and analyzed. The collars will be deployed once again on animals using the Marble Range prior to their migration to winter range in early November.

Ground inspection of the routes identified to date will be conducted during June 2000. Co-ordinates from the collar data will be input into hand-held GPS units and the routes covered on foot. Important terrain features, such as substrate, slope, and aspect will be documented and vegetation communities will be recorded for future analysis. Evidence of historical use (i.e. well-defined game trails) and pellet groups will also be recorded.

Upon completion of collaring efforts in the spring of 2001, all data will be collated and analyzed. Based on seasonal habitat use patterns, migration corridor definitions and requirements, recommendations for land use guidelines, specifically relating to mining operations and timber harvesting activities, will be developed and presented to local land use committees.

ACKNOWLEDGEMENTS

We thank D. Eyer, Director of the Clinton & District Outdoor Sportsmen Association (CDOSA), for his enthusiasm and tireless efforts in spearheading and supporting the project. The generous financial support of the following organisations is gratefully acknowledged: B.C. Environment, B.C. Parks, Nevada Bighorns Unlimited (Reno Chapter), Cariboo Chilcotin Helicopters Ltd., Clinton and District Outdoor Sportsmen Association, Foundation for North American Wild Sheep (Washington Chapter), Habitat Conservation Trust Fund, and the Wild Sheep Society of British Columbia.

Thanks to D. Smallman and B. Holt of Cariboo Chilcotin Helicopters Ltd. for skilful piloting during capture and relocation work. We appreciate the assistance of P. Bruno, S. Robinson, B. Ambler, D. Tegart and D. Yurkiew of CDOSA, with capture and collaring work. Special thanks to A. Norquay for his assistance with GPS data analysis, and to S. Lees and G. Watson for GIS mapping. Thanks to N. Christensen and C. Kochanny and K. Poole for their technical assistance with collars. We thank J. Carey and K. Ruckstuhl for review comments.

LITERATURE CITED

ADVANCED TELEMETRY SYSTEMS, INC. 1998. Deployment instructions. Included in Wildlink Data Acquisition and Recapture System Reference Manual Revision 1.7 (Draft).

KEYSTONE WILDLIFE RESEARCH. 1998. Churn Creek Bighorn Sheep Study: Summary Report. Prepared for Ministry of Environment, Lands and Parks. Williams Lake, British Columbia.

KINLEY, T. 1998. Comparison of GPS and VHF collars for use in the Central Selkirks caribou project. Prepared for Nanuq Consulting Ltd. Nelson, British Columbia, Canada.

MEIDINGER, D., AND J. POJAR. 1991. Ecosystems of British Columbia. B.C. Ministry of Forests Research Branch. Victoria, British Columbia, Canada.

MOEN, R., J. PASTOR, AND C. C. SCHWARTZ. 1996. Effects of moose movement and habitat use on GPS collar performance. Journal of Wildlife Management 60:659-668.

_____, _____, AND Y. COHEN. 1997. Accuracy of GPS telemetry collar locations with differential correction. Journal of Wildlife Management 61: 530-539.

NORQUAY, A. 1999. Draft: Assigning error values to 2 dimension, differentially corrected GPS positions collected from animal borne receivers. Prepared for British Columbia Ministry of Environment, Lands and Parks. Kamloops, British Columbia, Canada.

POOLE, K., AND D. C. HEARD. 1998. Habitat use and movements of mountain goats as determined by prototype GPS collars, Robson Valley, British Columbia. Biennial Symposium Northern Wild Sheep and Goat Council 11: 22-35.

_____. 1999. Low elevation forest use by mountain goats in the Robson Valley Forest District. Prepared for British Columbia Ministry of Environment, Lands and Parks. Prince George, British Columbia.

REMPEL, R. S., A. R. RODGERS, AND K. F. ABRAHAM. 1995. Performance of a GPS animal location system under boreal forest canopy. Journal of Wildlife Management 59:543-551.

_____, AND _____. 1997. Effects of differential correction on accuracy of a GPS animal location system. Journal of Wildlife Management 61:525-530.

RISENHOOVER, K. L., AND J. A. BAILEY. 1985. Foraging ecology of mountain sheep: implications for habitat management. Journal of Wildlife Management 49: 797-804.