Seasonal Habitat Use and Movement Corridor Selection of Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*), near Radium Hot Springs, British Columbia

2006 SEASON UPDATE

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INTRODUCTION

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) occur over 35 000 km^2 of the Rocky Mountains, mostly east of the Continental Divide, from 51' to 55' N (Stelfox 1978 in Poll *et al.* 1984b). Sheep are forced into a patchy distribution by their specific habitat requirements for low-snow winter ranges. Most sheep populations use between 2 and 3 different seasonal ranges; however, ram groups have been known to use up to 6 ranges and ewe groups up to 4 (Geist 1971). Bighorn sheep show high range fidelity, predictably returning to the same sites year after year via traditional migration routes. Winter ranges may be at high or low elevations, provided that wind, low precipitation, or high sun exposure result in low snow accumulation. Access to forage is critical to winter survival and may be hindered if snow cover is too deep. The East Kootenay sheep population winters on 6 low and 5 (known) high elevation ranges (Demarchi 1967). Summer ranges are usually at high elevation and may be located 1-40 km away from the winter range (Demarchi *et al.* 2000). Transitional ranges provide corridors between primary summer and winter ranges, and the loss of these corridors has been shown to increase sedentary behaviour (Demarchi and Demarchi 1994).

The bighorn sheep discussed in this report belong to the Radium-Stoddart herd, which numbers approximately 200 individuals (Dibb 2006). All subsequent use of the term "herd" refers to this particular group of sheep. Studies on the Radium-Stoddart sheep so far indicate limited (if any) exchange with neighbouring herds, which are present in the Beaverfoot Range (Golden Herd, maintained by Rod and Gun Club supplemental feeding), the southern Stanford Range (Columbia Lake Herd), and possibly the Mitchell Range (Kinley 2003). The Radium-Stoddart herd has been studied since the 1960s to determine range condition, movement patterns, demographics, and susceptibility to die-offs. In 1997, the community-based monitoring program Bighorn in Our Backyard was launched in the village of Radium Hot Springs, British Columbia. In 2002, the first 10 sheep were fitted with GPS collars, and a long-term study of ranges, migration routes, and response to grasslands restoration work was undertaken.

The GPS-radio collar study of Radium-Stoddart bighorn sheep is currently concluding its fifth consecutive field season. A comprehensive report was written regarding the 2002-2004 data and methodology (Dibb 2006), and a 2005 season update (Anderson 2006) was written as a supplement to the first report. This report serves as a further update for the 2006 season, but doesn't include any comparative analyses of data from all 5 seasons.

Ranges and Restoration

The Radium-Stoddart herd occupies ranges in the southern part of Kootenay National Park (KNP) and adjacent lands on the western slopes of the Rocky Mountains and the Columbia Valley. All habitat used by the Radium-Stoddart sheep occurs within the Southern Interior

Mountains ecoprovince, in the Western Continental Ranges and Southern Rocky Mountain Trench ecoregions (Kinley 2003). Summer ranges are in rocky alpine and krummholz habitats and winter ranges are on low elevation south-facing slopes near rocky outcrops or talus (Demarchi *et al.* 2000). Sheep, especially rams, may move as far north as Brisco and as far south as Windermere (Stelfox *et al.* 1985, Kinley 2003), and in 2006, one of the collared ewes (F410) moved as far north as Spillimacheen to her lambing range.

Summer habitat in the Brisco and Stanford ranges typically consists of alpine and upper subalpine ecosites of open forest and tundra. Moderate use also occurs in upper subalpine spruce/fir forest and on avalanche paths (Poll *et al*. 1984b). Although most of the summer is spent at high elevation, sheep also make short-term movements to lower elevation montane ecosites in search of forage or mineral licks (Poll *et al*. 1984b).

The winter range of Radium-Stoddart sheep extends along the western slopes of the Brisco and Stanford Ranges into the East Kootenay Trench (Kinley 2003). Sheep are predominantly found from Sinclair Creek south to Shushwap-Stoddart Creek, on low elevation (1300-1600 m) south- and west-facing colluvial slopes and glacial terraces above the Columbia Valley (Poll *et al*. 1984b). The regional climate is influenced by the Columbia River, associated wetlands, and Windermere Lake (Demarchi 1968 in Stelfox *et al.* 1985). Fall weather occasionally allows re-greening of some grasses, such as different varieties of bluegrass (*Poa* spp.) (Demarchi *et al.* 2000), which provide important autumn forage for bighorn sheep. Precipitation is about 2.25 times less on winter ranges (Stoddart Creek) than summer ranges (Sinclair Pass) (Stelfox *et al.* 1985).

Montane grasslands and open forests with low snow cover, as well as the residential, agricultural, and commercial areas of Radium Hot Springs, are used by the Radium-Stoddart herd as critical winter range (Poll *et al*. 1984b). The Springs Golf Course in Radium has become a highly frequented wintering area for sheep, as it provides a source of abundant, high-quality forage and may be relatively free of predators. Sinclair Canyon in KNP is an important transitional range until snow accumulates, and in mild winters sheep may return to the canyon to forage (Demarchi 1968 in Stelfox *et al.* 1985). Natural forage for the Radium-Stoddart herd includes wheat grasses (*Agropyron* spp.), fescues (*Festuca* spp.), bluegrasses (*Poa* spp.), needle grasses (*Stipa* spp.), forbs, and shrubs (Davidson 1991 in Demarchi and Demarchi 1994).

Historically, sheep winter range extended further into and along the Columbia Valley, but has since been reduced by forest ingrowth. Like many other Southern Interior valleys, the Columbia Valley was a fire-maintained ecosystem (Gayton 1996). Frequent, low intensity fires swept the valley bottom and extended up the western slopes of the Rockies (Kinley 2003). Fires

were intentionally set by First Nations people in order to maintain the grasslands and prevent forest ingrowth, or were the result of natural lightning strikes. A single veteran larch near Canal Flats, BC indicated periodic fires had occurred approximately every 26 years from 1589 to 1937 (Gayton 1996). Sediment cores from lakes throughout the East Kootenay Trench show high levels of sagebrush (*Artemesia tridentata*) pollen, further indicating a dry grassland ecosystem over much of the region (Gayton 1996).

As European settlers moved into the area, periodic natural fires were extinguished. Beginning around 1900, the fire regime of the area was disrupted and forest encroachment commenced. Ingrowth of shade-tolerant Douglas fir (*Tsuedotsuga menziesii*) into previously open forests (a few dozen to a few hundred stems per hectare) occurred when frequent seedling-killing fires were removed from the system (Gayton 1996). An ecosystem with an obvious canopy of mature western larch (*Larix occidentalis*), ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Tsuedotsuga menziesii*) was replaced by thick stands that included multiple age classes of Douglas fir, with stem densities of 10 000 stems/hectare or greater (Gayton 1996). Understory vegetation also shifted, from bunchgrasses to low-growing pinegrass (*Calamagrostis rubescens*). Pinegrass, unlike bunchgrass, does not undergo a re-greening in the fall, and also does not store protein in its stems. An over-abundance of pinegrass therefore means a reduction in the quality of winter forage available to bighorn sheep (Dodd *et al.* 1972 in Gayton 1996). Previously treeless grassland in the Columbia Valley was also overtaken by rapid forest ingrowth.

Although traditional bighorn winter ranges shrunk as forests expanded over them, it is the transitional ranges and migration corridors that have been the most severely affected by forest ingrowth, due to higher moisture regimes (Davidson 1991 in Demarchi *et al.* 2000). Migration routes between summer and winter ranges include the lower face of the Stanford Range, the Radium Hot Springs townsite, and the Sinclair Creek-Hwy 93 corridor (Kinley 2003). Reduced transitional ranges result in sheep spending more time on limited winter ranges, which can further degrade this habitat.

There are concerns that increased use of urban areas as winter range could be detrimental to the long-term health of the Radium-Stoddart herd. Sheep that frequent urban locations have been found to have higher parasite loads and lower lamb recruitment compared to sheep that do not utilize urban habitat (Rubin *et al.* 2002). The chance of mortality from railway and highway strikes also increases when urban locations form a part of bighorn habitat. It is estimated that over 10% of the Radium-Stoddart sheep are killed on highways each year (Dibb 2006). Another concern is the spread of pneumonia epidemics from domestic sheep, which are raised on several farms in the Columbia Valley. Grassland restoration work has been undertaken

near Kootenay National Park in the hope that it will provide habitat for the Radium-Stoddart herd away from urban and agricultural development.

Restoration efforts at Stoddart Creek and near Redstreak Campground (KNP) have attempted to mimic the open forest-grassland ecosystem of the pre-1900 Columbia Valley, providing more suitable habitat for sheep. The first site was restored in fall 2002, when the provincial block was selectively logged. Five-meter radii were cut around larger veteran trees, which were left in place. The second block, on federal land, was treated in fall 2003 using a different method. The federal block has leave patches of forest vegetation as well as scattered leave trees. The leave trees are typically in clumps, rather than arranged as single trees at a set distance. A prescribed burn was also conducted in the spring of 2005, followed by non-native plant control measures and some planting of native grasses. This project has restored 9.0% (173 hectares out of 1,913 total hectares) of historic Radium-Stoddart bighorn winter range (Parks Canada Agency 2006). GPS collar data collected during the 2002 season acts as a control, before restoration work was completed, and subsequent years show the shift in sheep ranges as they adapt to the new habitat.

(Introduction modified from Anderson 2006)

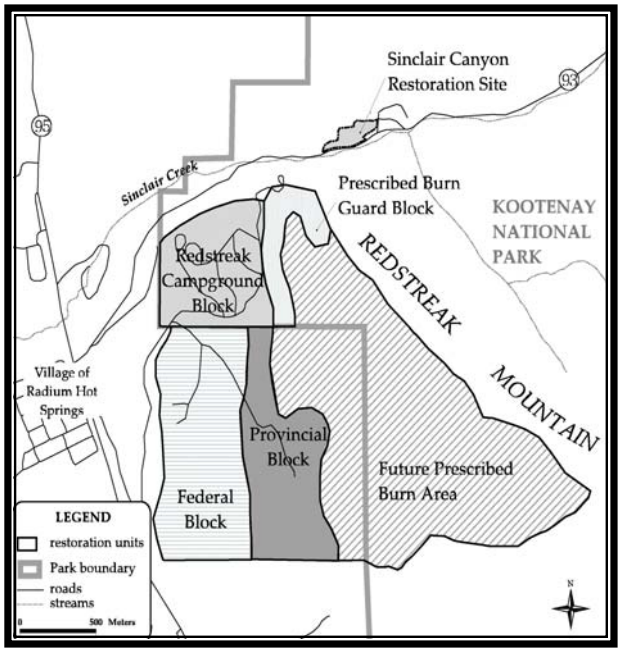

Figure 1a. Location of Redstreak Grasslands Restoration Area (left).

Figure 1b. Bighorn sheep grazing in the restoration area (above).

METHODS

More detailed methods are described in Dibb (2006). The formatting and methodology of this report have been modeled after Dibb (2006) and Anderson (2006). Eleven sheep were collared in the 2006 season: 3 rams and 8 ewes. All sheep were collared in or near the village of Radium Hot Springs, BC, which forms a part of their critical winter range. Collars were equipped with a 12-channel Garmin GPS engine and a high frequency VHF radio transmitter (Dibb 2006, Obee 2006). Collar function was checked before fitting and the sheep were also given plastic ear tags with identification numbers.

Sheep were immobilized using a Telazol-Xylazine-Hydromorphine mixture as a tranquilizer (Obee 2006). Dosages were based on the size of the animal (Obee 2006). Once a sheep was immobilized, it was blindfolded and its vital signs, including temperature, pulse, respiration rate, and oxygen saturation levels were continuously monitored (Obee 2006). Faecal samples for parasite load testing, and blood samples for disease assessment and possible future DNA studies were collected (Dibb 2006, Obee 2006). Girth was measured around the chest, just posterior to the animal's front legs (Obee 2006). Animals were weighed using a wildlife scale consisting of a net suspended from a metal tripod (Obee 2006). In order to help minimize handling time, sheep that appeared to be only mildly sedated were not weighed (Obee 2006). Once the appropriate samples were collected and the collars had been fitted, sheep were administered a reversal agent dosage of either Tolazoline-Naltrexone or Atipomazole-Naltrexone (Obee 2006).

Collars were programmed to attempt a GPS fix every 8.6 hours from the time they were deployed until April 31st. From the beginning of May onward, a summer schedule of GPS fix attempts every 3.25 hours was in effect. For F302 and F408, whose collars were not removed in the fall, the winter schedule resumed on November 16. A much shorter time interval between GPS fixes is required during the summer and during fall and spring migration periods, when sheep are traveling greater distances. In contrast, the sheep are much more sedentary while on their winter ranges, so less frequent fixes are necessary to track their movement.

The VHF transmitters on the collars were active daily between 8:00 and 17:00 local (mountain) standard time, so that collar function and animal location could be monitored using ground telemetry. The VHF signal emitted by each animal's collar was monitored at least once a week to check for mortality signals and GPS fix success rates, via a coded pulse system (Dibb 2006). Double-beeping signals indicated that the last attempt by the collar to establish a GPS fix had been successful. Single-beeps indicated a failed GPS fix attempt. A coded VHF mortality signal was emitted from a collar if the animal had not moved for more than 4 hours. We also

made an effort to visually locate the collared sheep on a regular basis in order to check for injuries, verify reproductive status of the ewes, and conduct group counts.

Collars were removed using a remote-release mechanism on November 1st and 2nd, once the sheep had returned to their winter range, with the exception of study animals F411 and M404, whose collars were removed earlier. F411's collar was removed in March and M404's in October, due to a collar malfunction and an injury, respectively. Collars were shipped back to the manufacturer (Advanced Telemetry Systems, Isanti, Minnesota, USA) for refurbishment and battery charges in preparation for next year's field season. The collars on F302 and F408 were left on to collect GPS data between November 2006 and January 2007. They will be removed sometime at the beginning of the new year.

RESULTS

Capture, Collar Deployment, and Collar Removal

Detailed accounts of individual animal capture and movement are located in Appendix I. F302 and M002 were re-collared from the 2005 study year, since their collars did not remote-release successfully. M002 has been collared annually since 2002, as he is easily recognized by a horn abnormality (see photos in Appendix II). This is, to our knowledge, only the second year that F302 has been collared. Future DNA tests could determine whether any sheep other than M002 have participated in the study for multiple years (Anderson 2006).

Estimated age at time of capture for rams was between 6.5-9.5 years, and for ewes was 2.5-8.5 years. F302 (6.5-8.5 years old) and F403 (3.5-4.5 years) were collared on the golf course on January 30th, 2006. M002 (8.5 years) was also collared on January 30th, but was captured behind the Radium Village office. F415 (2.5-3.5 years), M404 (8.5-9.5 years), and M405 (6.5-7.5 years) were collared on the golf course on January 31st. F407 (6.5-8.5 years) was collared the same day, northeast of Radium Elementary. Lastly, F402 (3.5 years), F408 (6.5-8.5 years), F410 (4.5-5.5 years), and F411 (6.5-7.5 years) were collared on the golf course on February 1st (Obee 2006). Only one of the rams (M405) was weighed, and was found to be 225 lbs. The average weight of female sheep that were captured was 171 lbs (Obee 2006). All captured animals were deemed to be in reasonably good health (Obee 2006).

Eight of the eleven sheep bedded down after the first tranquilizing dart (Obee 2006). The average time between darting and bedding down for these sheep was about 9 minutes, with a range of 6-15 minutes (Obee 2006). F302 and F407 both required a second dart and took 28 and 36 minutes to bed down, respectively. Immobilization of F411 necessitated a third dart, and total time before bedding down was 61 minutes (Obee 2006). The need for multiple darts was likely

the result of incomplete injection of the drugs from the first dart (Obee 2006). Average recovery time, measured as the time taken for a sheep to get to its feet following injection of the reversal drug, was 11 minutes, with a range of 2-21 minutes (Obee 2006). The dart used to immobilize one of the ewes (F408) became deeply embedded her right proximal tibia and was difficult to remove. Tetracycline was administered to prevent infection and Anafen was given as a painkiller. F408 was observed limping the day after she was darted, but had fully recovered and was walking normally a few days later (Obee 2006).

The collar on F411 had to be removed on March 14th, shortly after deployment, due to a malfunction that prevented it from obtaining any GPS fixes. It was discovered that one of the attachment screws had been driven through the GPS antenna wire (Figure 2) when the collar was first put on (Obee 2006). Since no GPS data was obtained from F411, she has been excluded from most of the following analyses. M404's collar was removed on October 19th because of an injury he sustained to his jaw, presumably during combat with other rams. Since M404's lower jaw was quite swollen, there was concern that the collar might restrict respiration or aggravate the injury, so it was removed. Trace amounts of blood were found on the collar following its removal. The collars on F302 and F408 were left on over the winter in order to obtain sheep movement data from November 2006 to January 2007. All other collar removals went as planned on November 1st and 2nd. There were no problems with the collars' remote-release mechanisms this year.

Figure 2. Antenna wire showing damage caused by fastening screw, from collar of study animal F411 (from Obee 2006).

GPS Collar Fix Success Rates

Table 1. GPS collar fix success rates, 2006

Sheep ID	Date collared	Date collar removed	Period of data collection (days)	Total fixes attempted	Total successful fixes	Fix success rate	3D fixes	2D fixes	3D Fix as % of fixes	3D Fix as % of fix attempts	Notes
M002	30-Jan-06	1-Nov-06	276	1604	1519	94.7%	1353	166	89.1%	84.4%	Normal operation
M404	31-Jan-06	19-Oct-06	262	1518	1405	92.6%	1225	180	87.2%	80.7%	Removed early due to injury
M405	31-Jan-06	2-Nov-06	276	1620	1523	94.0%	1373	150	90.2%	84.8%	Normal operation
F402	1-Feb-06	1-Nov-06	274	1609	1515	94.2%	1386	129	91.5%	86.1%	Normal operation
F403	30-Jan-06	1-Nov-06	276	1615	1571	97.3%	1476	95	94.0%	91.4%	Normal operation
F407	31-Jan-06	1-Nov-06	275	1616	1522	94.2%	1421	101	93.4%	87.9%	Normal operation
F410	1-Feb-06	1-Nov-06	274	1609	1441	89.6%	1197	244	83.1%	74.4%	Normal operation
F411	1-Feb-06	14-Mar-06	42	116	0	0.0%	0	0	0.0%	0.0%	Removed early due to GPS malfunction
F415	31-Jan-06	1-Nov-06	275	1613	1519	94.2%	1365	154	89.9%	84.6%	Normal operation
	2006 Average % and Totals:		2230	12920	12015	93.9%*	10796	1219	89.8%*	84.3%*	

* Data from F411 discounted from average percentage calculations

**no GPS fix success data for F302 and F408, since collars were not removed in the fall

Table 2. Comparison of actual fix success rates with the percentages suggested by telemetry monitoring

Sheep ID	Actual fix success rate	# of checks	# of double-beep checks	# of double-beep checks predicted based on fix success rate
M002	94.7%	103	102	97.54
M404	92.6%	92	91	85.19
M405	94.0%	84	80	78.96
F402	94.2%	109	100	102.68
F403	97.3%	104	96	101.19
F407	94.2%	95	89	89.49
F410	89.6%	104	95	93.18
F411	0%	13	0	0
F415	94.2%	103	99	97.03

GPS Collar Fix Success Rates

Collars had an average GPS fix success rate of 93.9% (Table 1). Of these successful fixes, 89.8% were three-dimensional (3D) points. A total of 10,796 3D GPS points were recorded over 2,230 days of data collection by nine collars (however, note that F411's collar did not contribute any data points over the 42 days it was deployed). GPS fix success rates remain to be calculated for the collars of study animals F302 and F408, since the data from these collars has not yet been retrieved. The fix success rates calculated from collar data did not appear to differ from those predicted by telemetry monitoring of collar function (see Table 2).

Mortalities and Injuries

All reported sheep mortalities, both inside and outside Kootenay National Park, were investigated and documented. No collared sheep died during this year's study. Sixteen sheep mortalities were documented between January and November of 2006. Eleven of these mortalities were attributed to highway or railway collisions. There was also one reported highway strike, in which a sheep was hit but managed to run away. It is likely that this sheep also died; however, death could not be confirmed since the carcass was not recovered. Another death was indirectly caused by highways; a subadult ram became trapped in Sinclair Canyon after being frightened by oncoming traffic and was subsequently swept over the falls. It is estimated that annual highway mortality for Radium-Stoddart sheep may now be greater than 10% of the total population. This estimation is based on current assessments of herd size (fall 2006 total daily counts) and the number of recorded highway mortalities. While both of these figures may be somewhat underestimated, highway mortalities are likely more so, since many deaths caused by vehicle strikes go unrecorded. If this were the case, highway strikes would account for an even greater proportion of herd mortality.

In February, an ewe was observed in respiratory distress on the golf course (Obee 2006). She died shortly after and was taken to the veterinarian in Invermere for necropsy (Obee 2006), where cause of death was determined to be a severe infection of bacterial pneumonia (*Pasteurella trehalosi*). Another ewe was found dead near the Radium Hot Pools, behind a highway guardrail. Based on the surrounding terrain, broken bones, and internal injuries revealed during necropsy, the cause of death was probably a fall. Two sheep also died of unknown causes. See Figure 3 for a summary of known sheep mortalities in the Radium-Stoddart herd between January and November, 2006.

Sheep were regularly checked for physical condition and abnormalities. Two relatively serious injuries were noted for study animals M002 and M404 between September and December of 2006. M404's collar was removed in October due to a severely swollen and possibly

broken jaw. This injury probably resulted from combat with other rams during the rut, since M404 also had a freshly broomed right horn-tip. M404 was seen again on November 1st at the golf course entrance, still with a swollen jaw (Figure 4); however, he continued to engage in combat with other large rams. He has not been seen since. M002 was observed favouring his right foreleg during the week of November 12th-18th. The limp appeared to gradually improve over the next few weeks of observations.

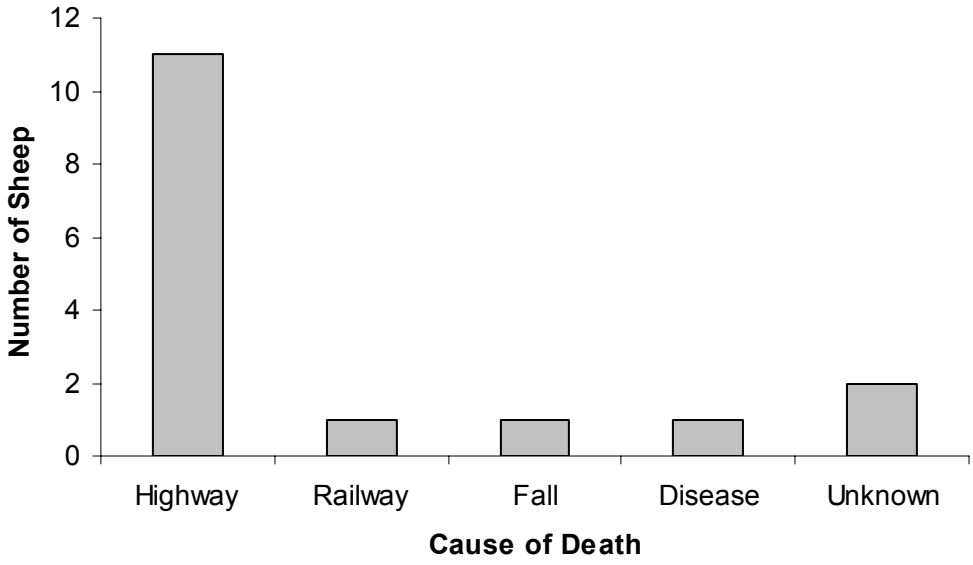

Figure 3. Causes of bighorn sheep mortality in the Radium-Stoddart herd from January to November, 2006.

Figure 4. M404 (left) showing broomed horn tip and swollen lower jaw, November 1st, 2006.

Lamb Production and Lambing Areas

Lamb:ewe and lamb:adult ratios were estimated from the largest daily counts that did not include high numbers of unclassified sheep. These ratios are expressed as the estimated number of lambs per 100 ewes or 100 adults. For the purposes of these calculations, 'adult' sheep were defined as all sheep 1 year of age or older, of either sex, and 'ewes' are defined as female sheep 2 years of age or older (i.e. female yearlings excluded). Lamb ratios were calculated for two seasons: spring, or February to April 2006 (lambs born in spring 2005 and approaching 1 year of age) and fall, or October to November 2006 (lambs born in spring of the same year). Observations during the summer were not used in ratio calculations, as ewe herds are dispersed over high-elevation summer ranges and cannot be easily counted. For spring counts, the lamb:ewe ratio was 35:100 and the lamb:adult ratio was 22:100. For fall counts, the lamb:ewe ratio was 61:100 and the lamb:adult ratio was 33:100.

Of the 7 females that remained collared into the summer, 4 were confirmed with lambs (F402, F408, F410, and F415), all of which appeared to survive until fall. Two collared females (F302 and F403) probably did not have lambs this year. Lamb status for the final ewe, F407, is unknown, but it is likely that she did not have a lamb this year. The lamb:ewe ratio for collared animals is between 57:100 and 71:100, depending on F407's lambing status.

Ewes usually remain within a small area for a few days during lambing, so lambing sites should be indicated by a collection of several GPS points at almost the same location (Anderson 2006). In some cases, multiple areas of concentrated points were observed during the lambing season, making it difficult to determine the exact lambing site. Lambs are usually born during late spring or early summer, following a gestation period of approximately 175 days (Geist 1971). Lambing sites for Radium-Stoddart ewes were generally located in steep sections of the southern Brisco Range. F410 was the only exception, as she traveled to the northern end of the Briso Range near Spillimacheen to have her lamb. Potential lambing sites varied in aspect, most being south or southwest, however a northeastern site was also recorded. Collared ewes remained at lambing sites for 4-8 days before proceeding to traditional summer ranges. F410 moved slightly further north after lambing, but soon returned to areas used by the other collared females in the Southern Brisco Range. See Table 3 for possible lambing sites of collared ewes.

Table 3. Description of possible lambing sites for 2006 collared ewes

ID #	Possible Lambing Site	Time Spent	Aspect	Notes
F402	Cliffs just southwest of Mt. Berland	May 6-14	E/NE	Lamb confirmed
F407	Southern ridge parallel to lower Sinclair Trail, directly east of Mt. Berland summit	May 19-26	SW	F407 lamb status unknown
F410	Cliffs northeast of Spillimacheen	May 30-Jun 2	S	Lamb confirmed
F415	Cliffs north of Hot Pools, SSE of Mt. Berland	May 7-13	S	Lamb confirmed

*Lambing sites not determined for F411 (collar removed too early) or for F302 and F408 (collars not released)

Counts and Classification

The largest groups (117, 116, 114 and 104) were seen on the winter range in February-March and October-November. Total daily counts greater than 100 were recorded from January-May and October-November. The highest total daily count this year was 168 sheep on February 16th, with classified counts of 31 for young-of-year (YOY), 1 for yearlings (YLY), 91 for females, 14 for Class I, 11 for Class II, 17 for Class III, and 0 for Class IV rams. In the fall, the highest total daily count was 139 sheep on November 24th, with classified counts of 31 for YOY, 7 for YLY, 56 for females, 16 for Class I, 10 for Class II, 13 for Class III, and 0 for Class IV rams.

The largest group size observed on high-elevation summer range was 39 sheep, seen on July 18th. Total daily counts of 48, 41, and 30 in July and August were the greatest to be recorded while sheep were on summer range. Since sheep are so widely dispersed during the summer, and because high-elevation ranges are not easily accessible, total daily counts are not considered representative of herd size as a whole at this time of year.

Sheep were segregated in ewe-lamb groups and ram groups for most of the year, mingling only on rut and winter ranges. Ewe-lamb groups consisted primarily of females and YOY, with relatively smaller numbers of YLY and Class 1A and 1B subadult rams. Each collared sheep was observed at least once with all of the other collared sheep, regardless of sex. See Figures 5 and 6 for summaries of group and total daily counts made throughout the 2006 study year. As of fall 2006, the minimum estimated size of the Radium-Stoddart herd is approximately 140 individuals (based on total daily counts). The actual number of animals is likely greater, as counts cannot be guaranteed to include 100% of individuals on any given day.

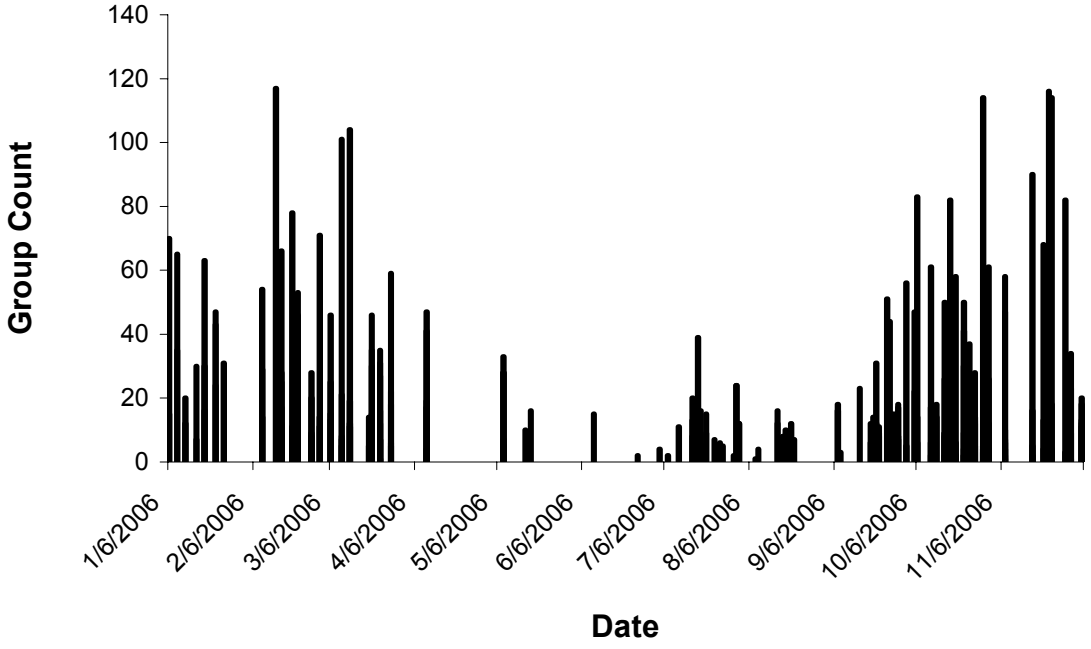

Figure 5. Group sizes observed in 2006, indicating number of sheep in a single group.

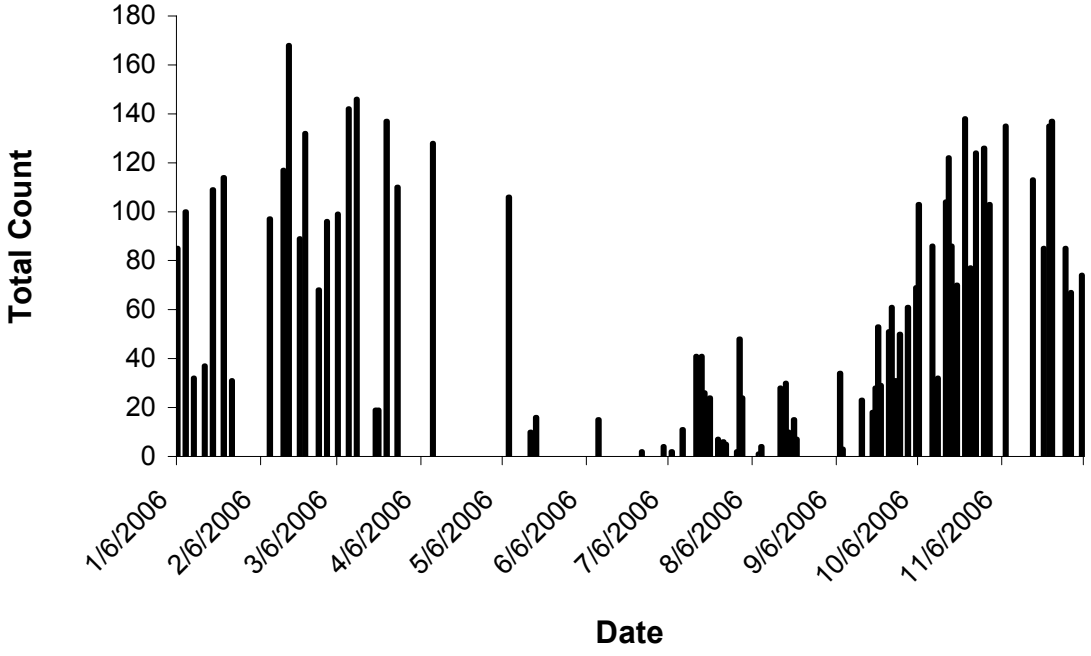

Figure 6. Total daily counts of Radium-Stoddart sheep throughout the study year.

Use of Mineral Licks

Sheep were observed licking minerals at the Sinclair trailhead and at the salt shed above the McKay Creek compound. F402, F407, and F408 were seen at the McKay salt shed and F402, F407, and M405 were seen at Sinclair. Sightings of collared animals at mineral licks occurred between mid-May and early August, in groups of 10-24 sheep. A total of 15 visits (confirmed either by sightings or GPS points) were made to the mineral licks, 6 at McKay and 9 at Sinclair. In addition, collared sheep made 16 other possible visits to mineral licks. A 'possible' visit was any movement for which the GPS points showed a sheep within close proximity to a mineral lick; however, no points were actually recorded at the site. These totals are likely to increase once GPS data is retrieved from the collars of F302 and F408. GPS points near mineral licks were logged from May to September, generally between 11:00 and 17:00 Mountain Standard Time. Collared ewes made an average of 2.80 (confirmed data only) visits to mineral licks, while the only confirmed visit by a ram was to Sinclair in late July (M405). The number of visits made to each mineral lick by collared rams and ewes is summarized in Figure 7.

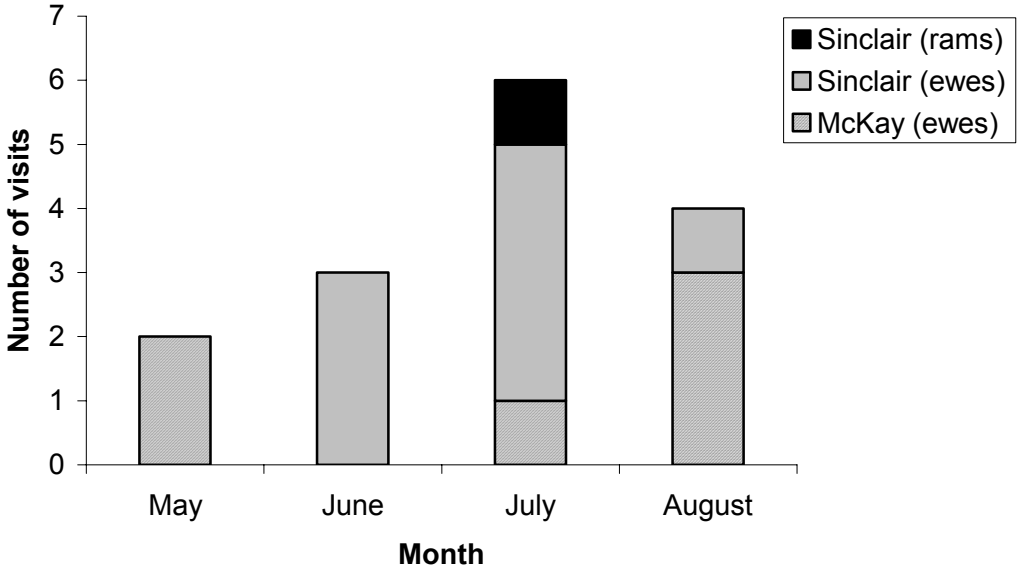

Figure 7. Total number of confirmed visits made by collared ewes and rams to mineral lick sites at the McKay Creek compound and the Sinclair trailhead.

Home Ranges, Seasonal Ranges and Migratory/Dispersal Movements

I used ArcGIS software to calculate minimum convex polygon (MCP) and 90% kernel home ranges for collared sheep. For the purposes of calculating MCP home ranges, any outlying 2D points with PDOP (position dilution of precision) values greater than 6.0 were deleted; however, this only turned out to be necessary for one point logged by F402. Out-lying points that

were 3D and had reasonable PDOP (<6.0) values were still included in home range calculations. Home range areas for individual sheep are presented in Table 4 and Figures 8-10. The average MCP home range for ewes was 171.20 km^2 (n= 5, SD= 132.91 km^2). The average MCP home range for rams was 180.16 km^2 (n= 3, SD= 32.36 km^2). Average 90% kernel ranges were 43.65 km^2 for ewes (n= 5, SD= 21.85 km^2) and 49.93 km^2 for rams (n= 3, SD= 3.71 km^2). MCP and 90% kernel home ranges generated for study animal F410 were extremely large, due to an extensive northerly movement she made during the spring, most likely to her lambing site. The disproportionate results for F410 are reflected in the large standard deviations calculated for average MCP and 90% kernel ewe home ranges (see above). For this reason, the average ewe home ranges listed above are probably over-estimated. MCP and 90% kernel home range sizes for collared sheep are listed in Table 4 and shown in Figures 8-10.

Table 4. Minimum convex polygon and 90% kernel home range sizes of individual 2006 study animals

Sheep ID	MCP Home Range (km^2)	90% Kernel Home Range (km^2)
M002	143.44	47.89
M404	192.57	54.22
M405	204.48	47.69
F402	76.63	26.75
F403	161.30	43.34
F407	109.25	34.38
F410	402.62	81.26
F415	106.20	32.53

All of the sheep were concentrated around Radium when the collars were first put on in late January and early February. For the purpose of analysis, the winter range was divided into 5 areas: Radium north, Radium village and golf course, the admin. road, Redstreak Restoration Area, and the Mile Hill (Figure 11). In February, collared females spent most of their time on the golf course; however, the Radium townsite, Radium north, and the admin. road were also used. Only a few points were logged on the northern edge of the Mile Hill area for collared ewes. Between March and April the same areas continued to be frequented by ewes, but areas east of Radium in Sinclair Canyon and the Redstreak Campground were also used. Females began the spring migration to their lambing ranges in May. Most of the ewes lambed and spent the rest of the summer along the high-elevation ridges of the southern Brisco Range, although F410 journeyed northward to Spillimacheen in early summer to have her lamb, after which she returned to the Brisco Range.

In February and March, collared rams were found mainly on the Mile Hill, the golf course, Radium North, and on the admin. road. A few points were also logged in the village itself and east in Sinclair Canyon. Males generally made greater use of the Mile Hill as winter range than did females, but were found less often in Radium village at this time. In April, the collared rams shifted their winter range eastward toward the West Gate and the Redstreak Restoration area, as well as remaining on areas previously utilized in February and March. In May, the same areas continued to be used; however, additional easterly points were also logged in Sinclair Canyon. By the end of May, M405 had completed his spring migration to the Stanford Range, where he spent the majority of the summer. The other two collared rams began migrating in early June and spent the summer in the southern Brisco Range.

In September, female sheep began their fall migration southwest from the Brisco Range and back into Radium. Ewes spent the month of October primarily in southwest Radium and on the golf course, while a few points were also logged in Sinclair Canyon near the hot pools. Information on ewe movements from November-January (i.e. during the rut) will be available when data is retrieved from the collars of F302 and F408 early in 2007. Males began their fall migration in October, a month later than females. After arriving in Radium, collared rams spent the remainder of the month in the village and golf course areas. The Sinclair Canyon and HWY 93S corridor (west of McKay Creek) was a significant transitional area used by sheep in both the spring and fall.

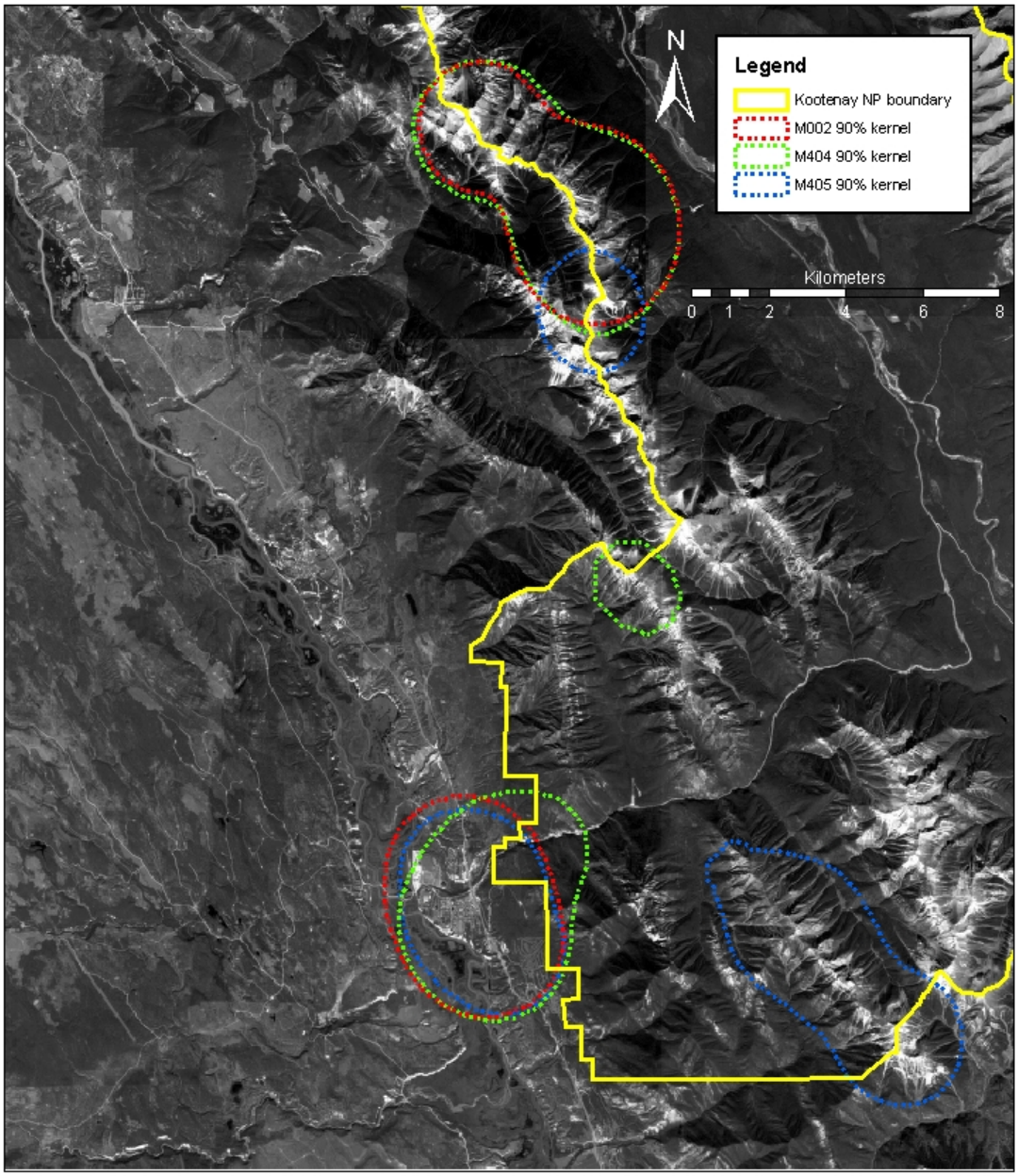

Figure 8. 90% kernel home ranges for collared rams.

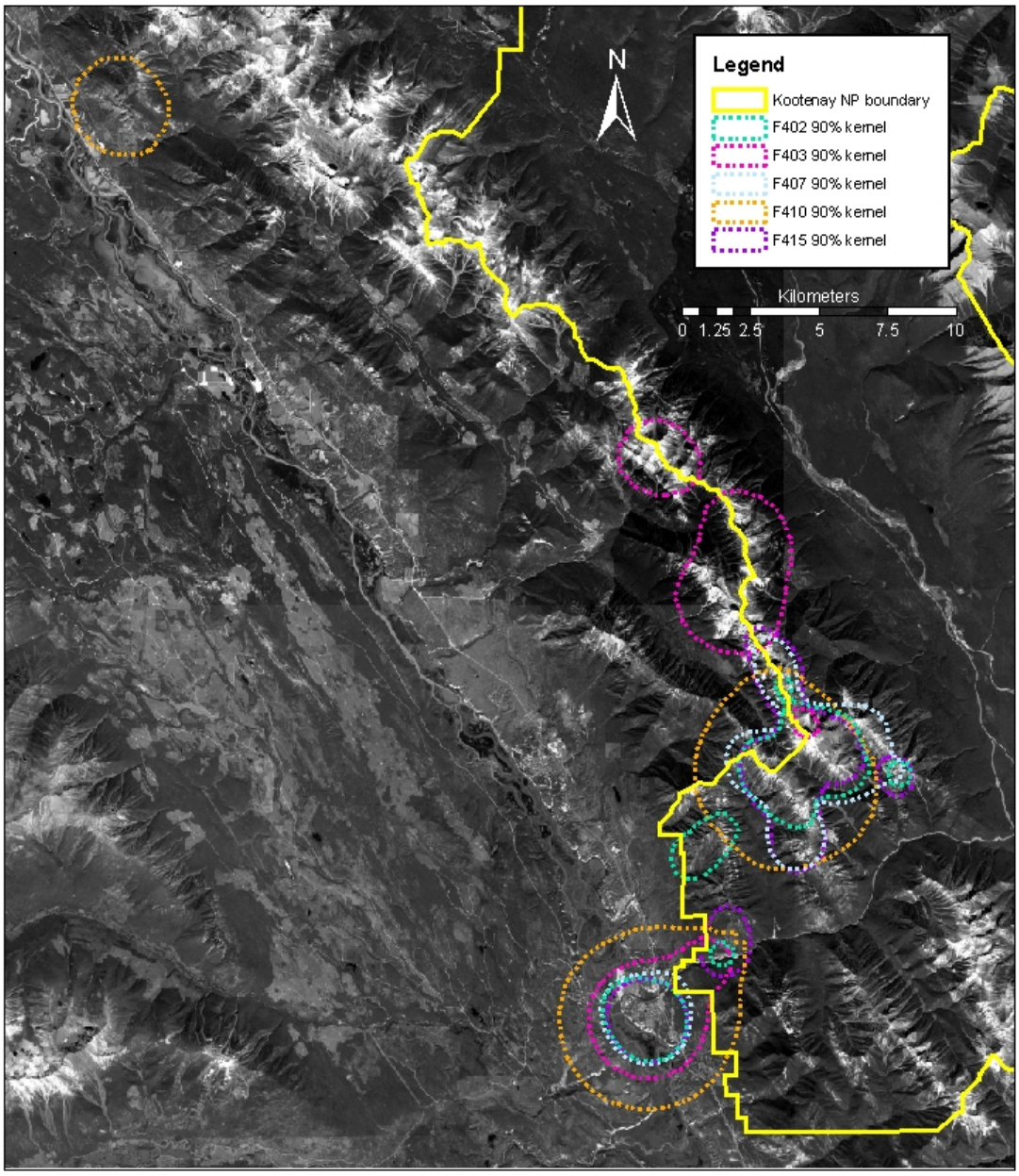

Figure 9. 90% kernel home ranges for collared ewes.

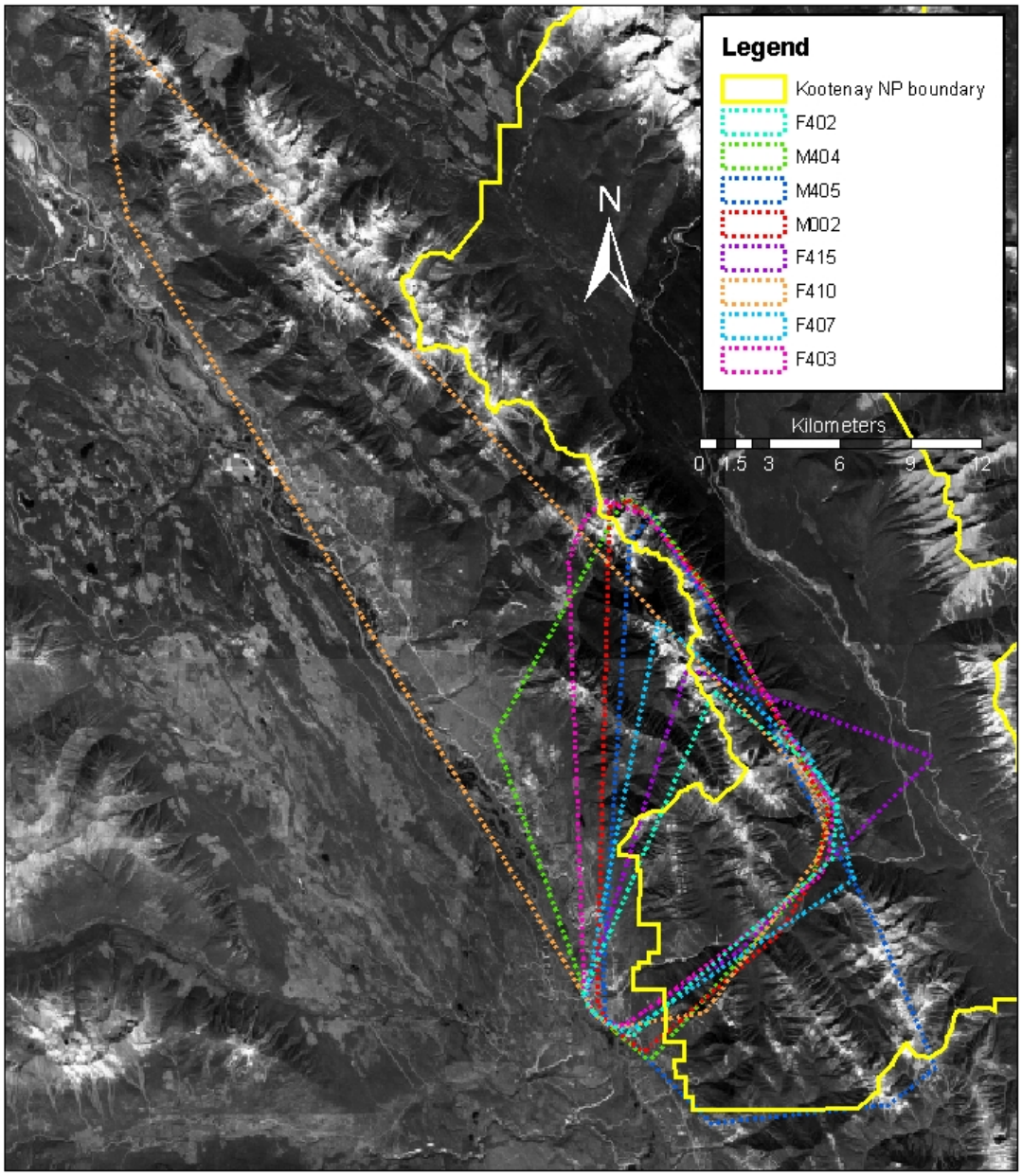

Figure 10. Minimum convex polygon home ranges for 2006 study animals.

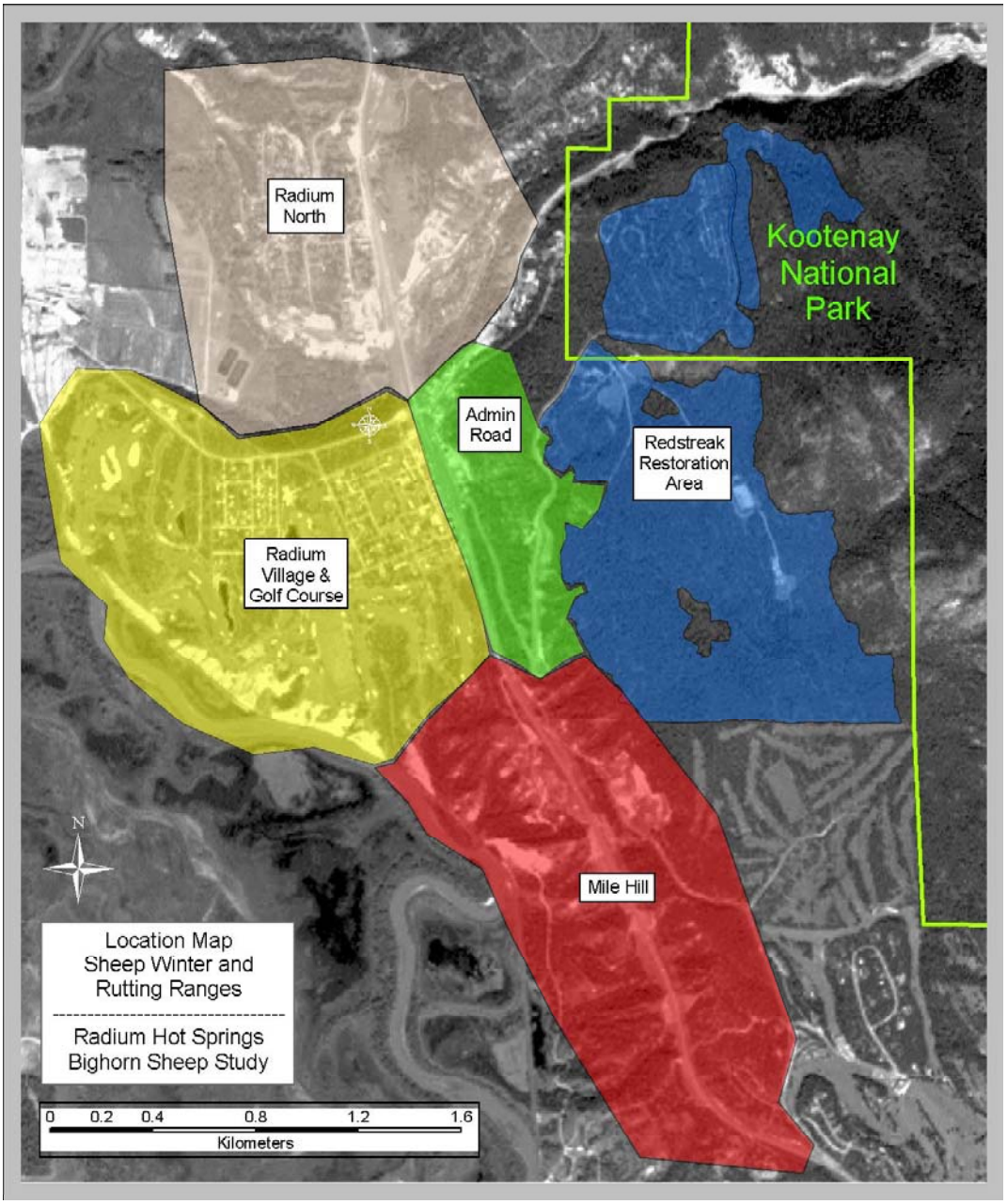

Figure 11. Areas of bighorn sheep winter range referred to in this report. (from Dibb 2006)

Use of Terrain

Figures 12-19 show the elevations of collared sheep throughout the study year. The average date of spring migration to high elevation was May 13th for collared ewes (SD= 7.04 days, n= 5) and June 5th for rams (SD= 9.50 days, n= 3). The average date of fall migration to low elevation was Sept 17th for ewes (SD= 9.36 days, n= 5) and Oct 19th for rams (SD= 4.36 days, n= 3). For the most part, migrations between seasonal ranges occurred rapidly within a few days, particularly in the fall. F410 and F415, however, made a less abrupt transition to summer habitat than the other collared sheep, cycling from low to high terrain until finally settling on their summer ranges (Figures 15 and 16). Once arriving at high elevation summer range (>1200 m), sheep did not leave again until the fall migration to winter range, with the exception of a few short visits to low elevation sites. On average, ewes made more short-term movements to low elevation sites (presumably mineral licks) during the summer than did rams. M405 made one longer excursion to low elevation during the summer that lasted from June 27th to July 4th (Figure 18). Average monthly elevations for collared ewes and rams are shown in Figure 20. Ewes tended to leave for high elevation approximately one month earlier than rams, but also returned to winter range one month earlier.

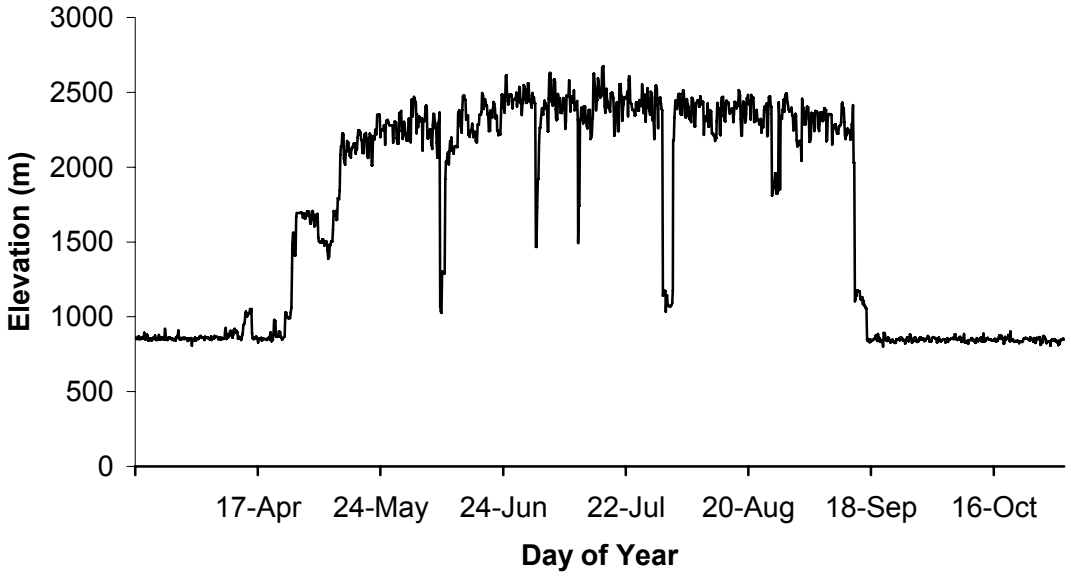

Figure 12. F402's elevation over the year 2006.

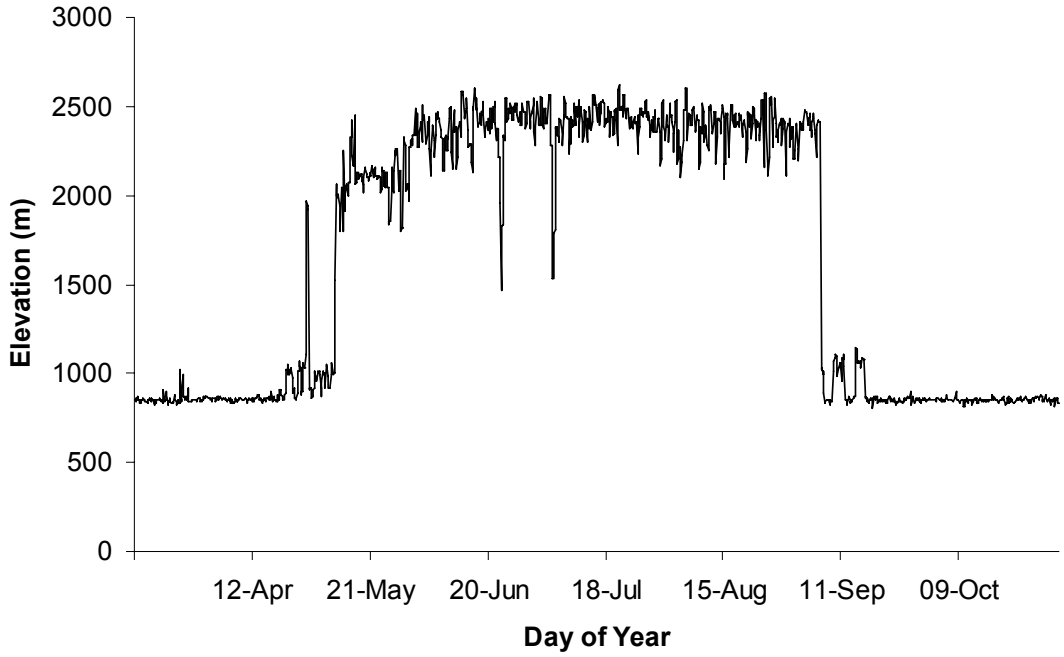

Figure 13. F403's elevation over the year 2006.

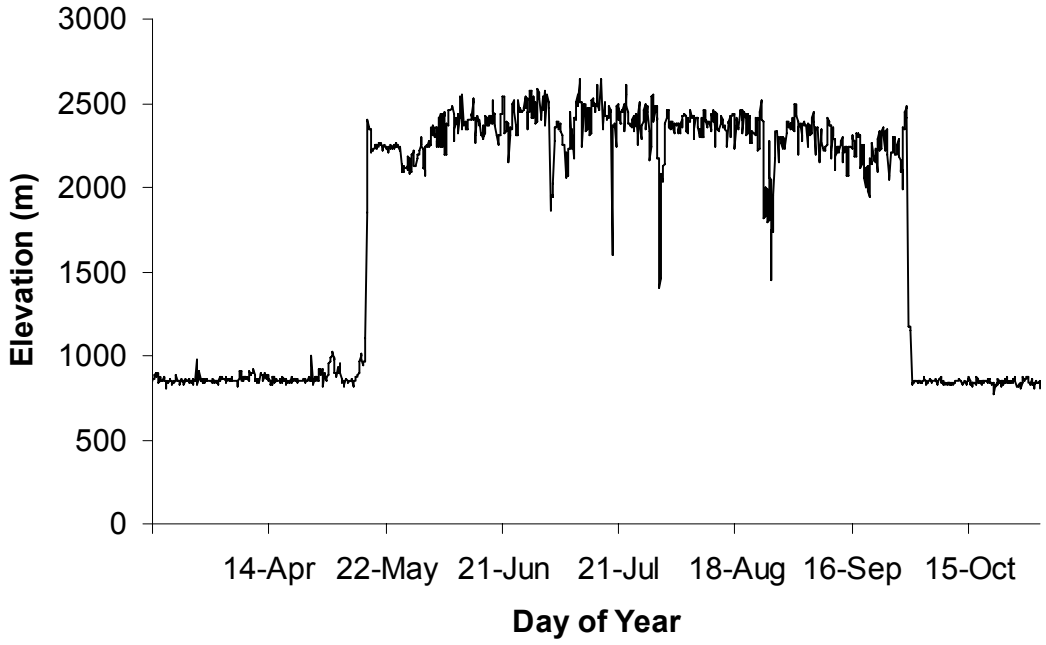

Figure 14. F407's elevation over the year 2006.

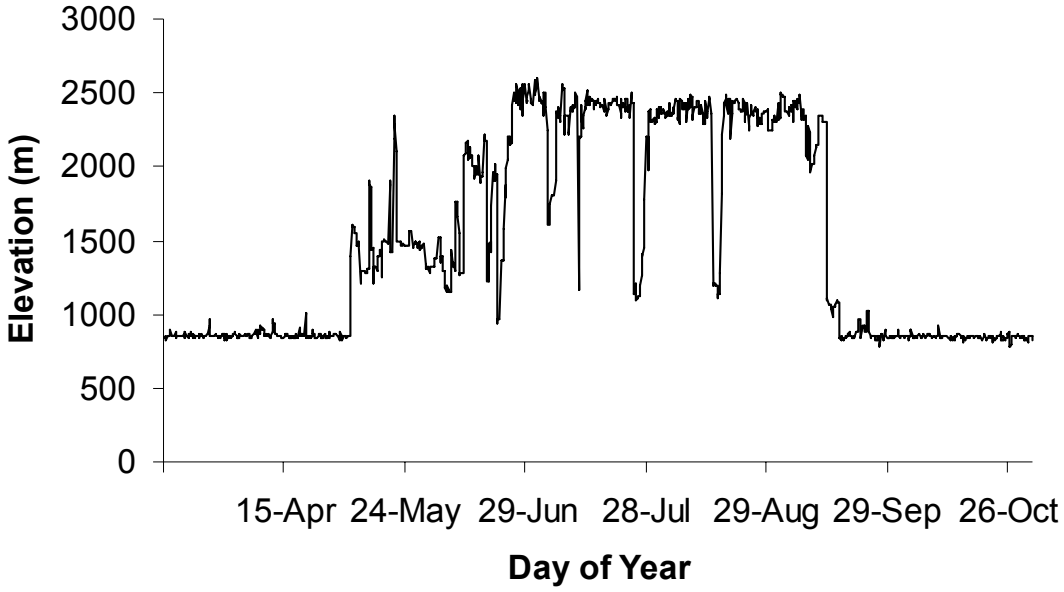

Figure 15. F410's elevation over the year 2006.

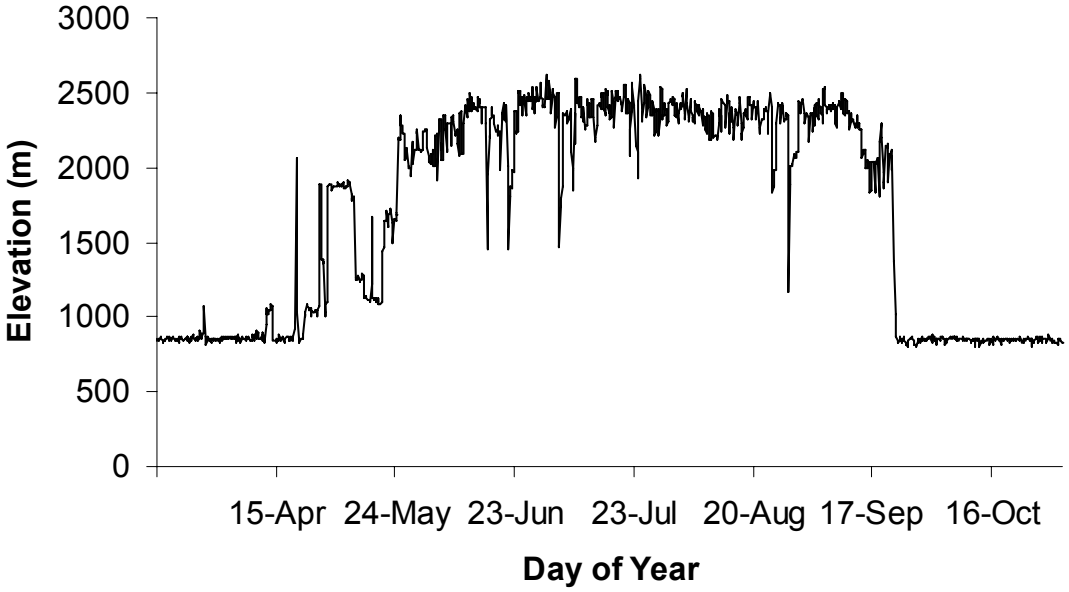

Figure 16. F415's elevation over the year 2006.

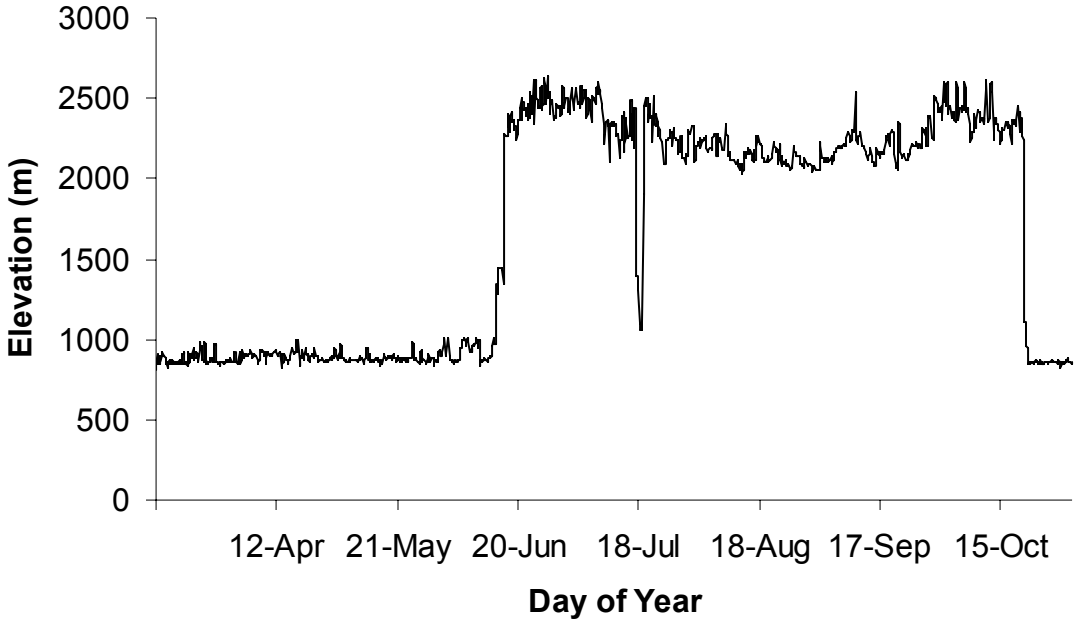

Figure 17. M002's elevation over the year 2006.

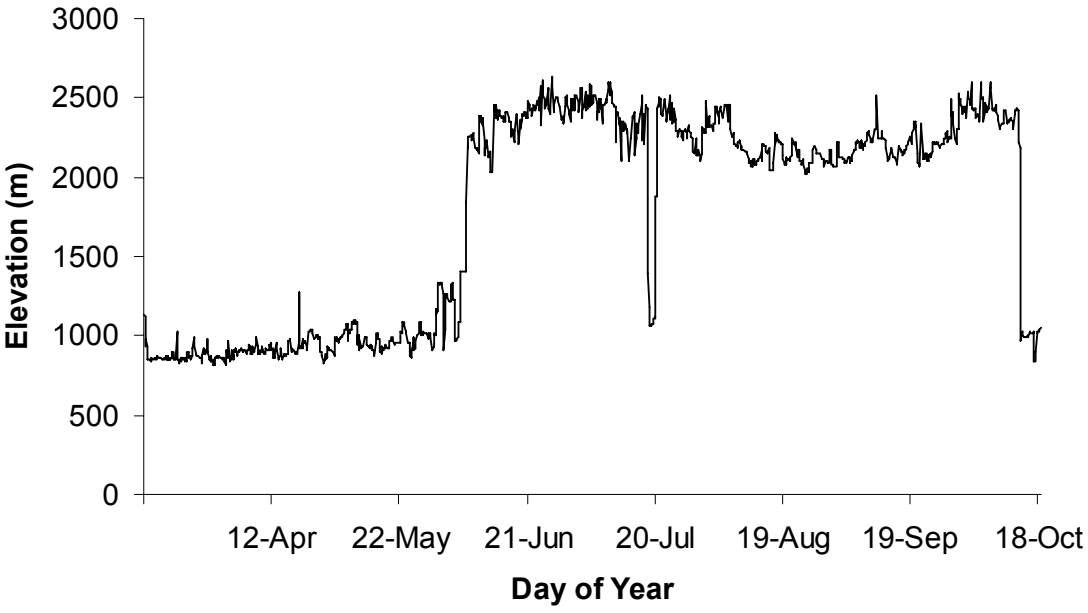

Figure 18. M404's elevation over the year 2006.

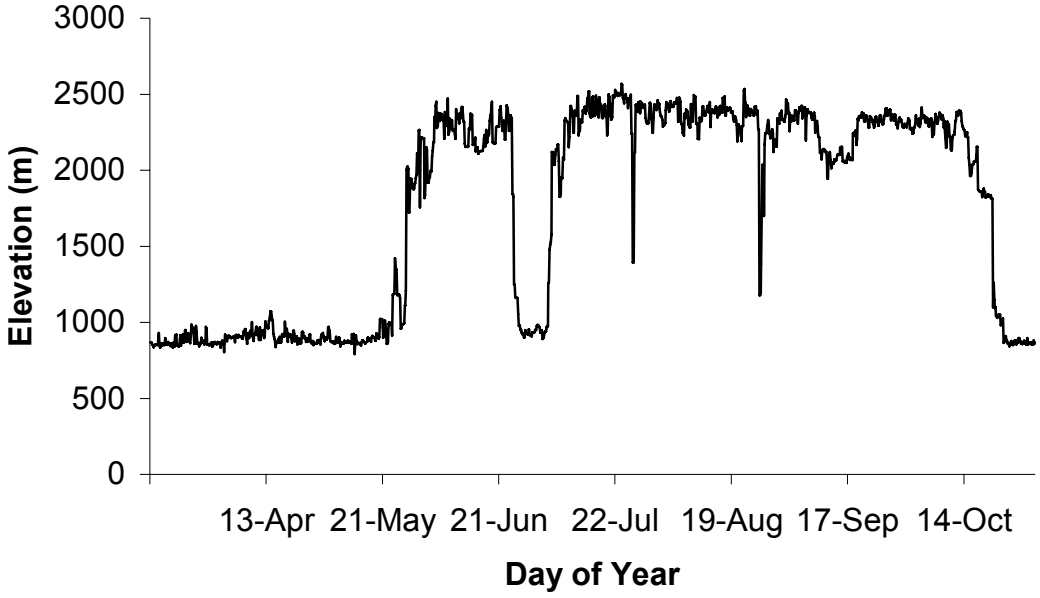

Figure 19. M405's elevation over the year 2006.

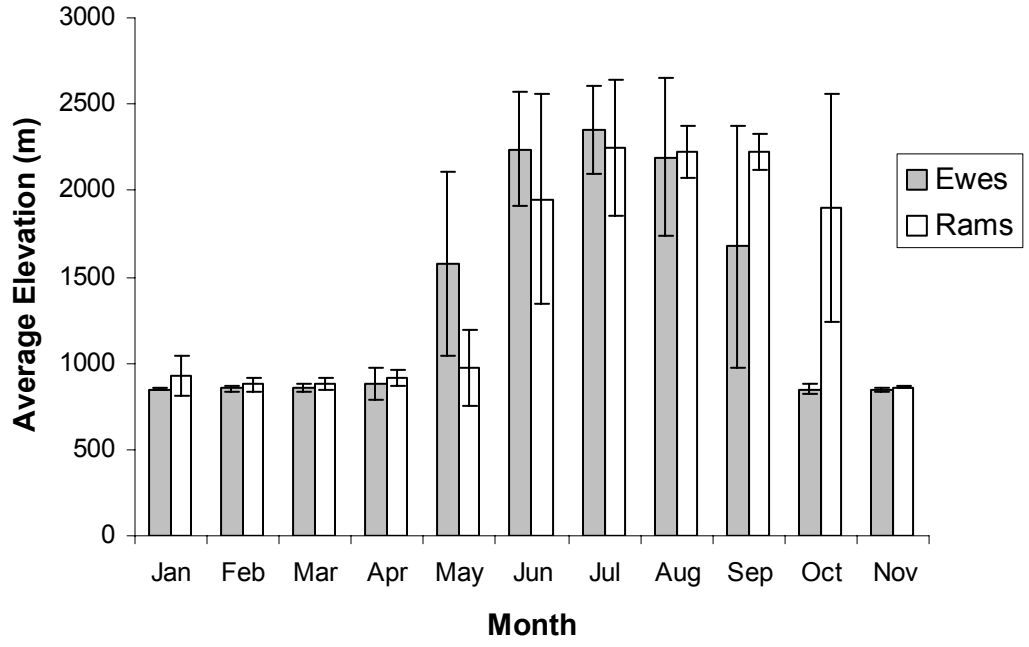

Figure 20. Average elevation by month for ewes and rams, error bars indicate ± standard deviations.

Domestic Sheep Issues

There are 4 domestic sheep ranches located near areas frequented by collared sheep from the Radium-Stoddart herd in 2006: Spillimacheen, Edgewater, Firlands and Shuswap Creek. All GPS points were included in this analysis, regardless of their PDOP values or whether or not they were 3D. Locations of domestic sheep farms, surrounding 2 and 5 km circular buffer zones, as well as the bighorn GPS points within these zones, are shown in Figure 21. The number of GPS points located within the 2 and 5 km buffer zones for each domestic sheep site are summarized in Table 5.

All points near the Spillimacheen site were the result of the lambing activity of sheep F410, whose collar recorded 13 points within the 2 km buffer and 179 within the 5 km buffer. At the Edgewater site, all of the points within the 5 km buffer, except for one logged by M404, were also recorded by F410 during migration to and from her lambing range. The majority of points occurring near a domestic sheep ranch (4608) were within the 5 km buffer of the Firlands site, which is quite close to the village of Radium and critical winter range used by bighorn sheep. However, there were no points recorded within the 2 km buffer for this site. Two points were recorded by M405 within the 5km buffer of the Shuswap Creek site.

Table 5. Bighorn telemetry points in proximity to domestic sheep ranches

Domestic Sheep Location	Points within 5 km Buffer	Points within 2 km buffer
Spillimacheen	179	13
Edgewater	35	0
Firlands	4608	0
Shuswap Creek	2	0
TOTALS:	**4824**	**13**

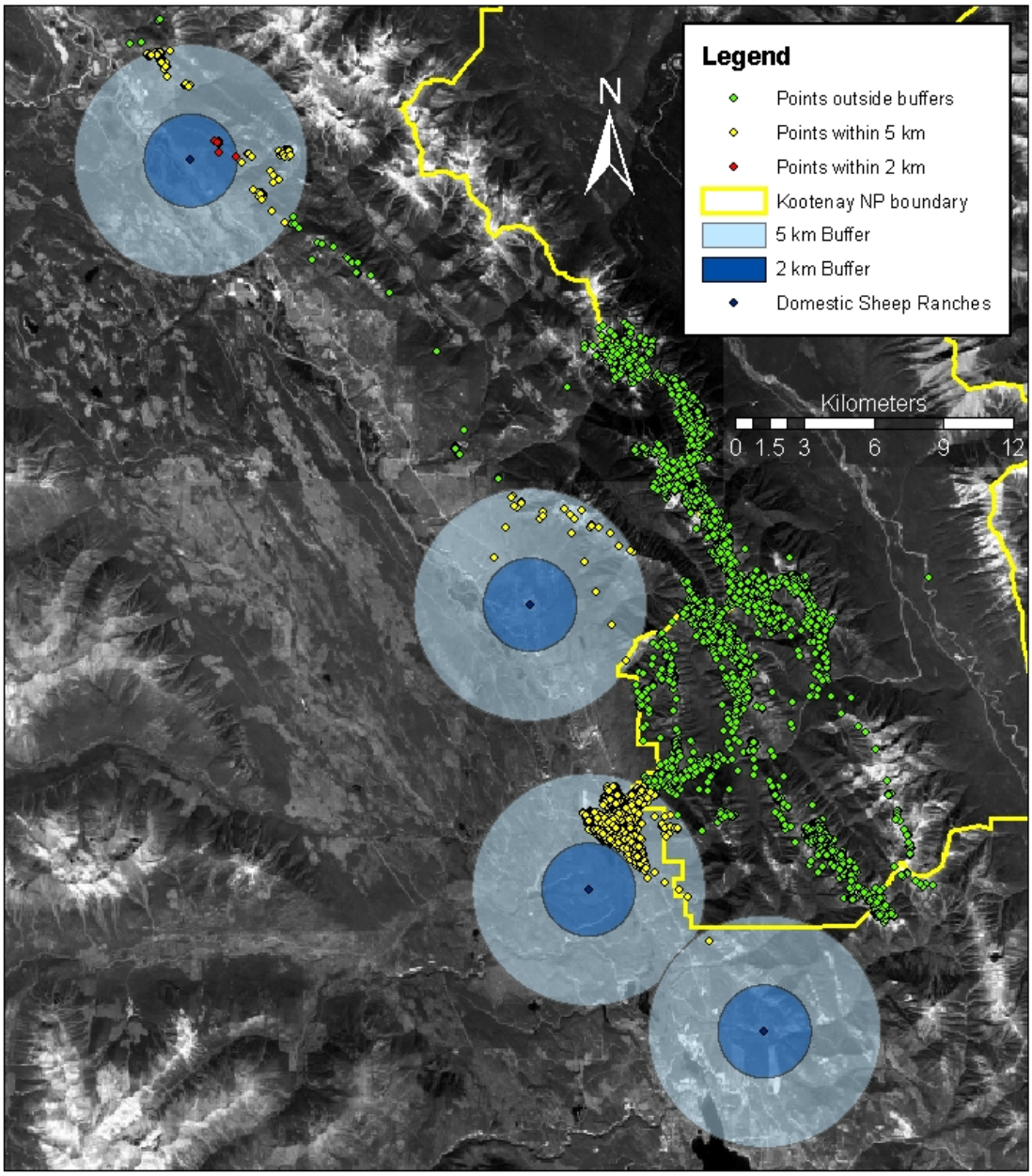

Figure 21. Proximity of bighorn telemetry points to domestic sheep farms in the Columbia Valley. (From north to south: Spillimacheen, Edgewater, Firlands, and Shuswap Creek)

Use of Kootenay National Park Versus Out of Park Areas

For this analysis, only "daily" telemetry locations were considered, meaning that a maximum of one 3D point (with PDOP<6.0) per animal per day (daylight hours only) was used. This reduces the chance of temporal autocorrelation of successive data points, as well as eliminating inaccurate points (Dibb 2006). In 2006, 41.37% of sheep daily telemetry locations occurred within Kootenay National Park. In winter (October-April), only 6.86% of daily telemetry locations were within KNP, but in summer (May-September), 68.29% of locations were within KNP. Since most collars did not remain on for the months of December and January, however, all year and winter figures may be biased toward locations within the park. This bias is reduced or eliminated by considering daily telemetry location data on a monthly basis (Dibb 2006), as shown in Figure 22. Use of the park drops to less than 10% for both males and females between October and April. Highest use of KNP by collared ewes was in July, when over 80% of the daily telemetry points were within park boundaries. For rams, peak use of KNP occurred in September, when more than 90% of points were recorded within the park. Most of the daily points outside KNP were collected while sheep were on their winter range in Radium and the surrounding areas (Figure 23). However, some points outside KNP were recorded during the summer along the western park boundary, as well as those recorded by F410 during spring migration to her lambing range near Spillimacheen (Figure 23).

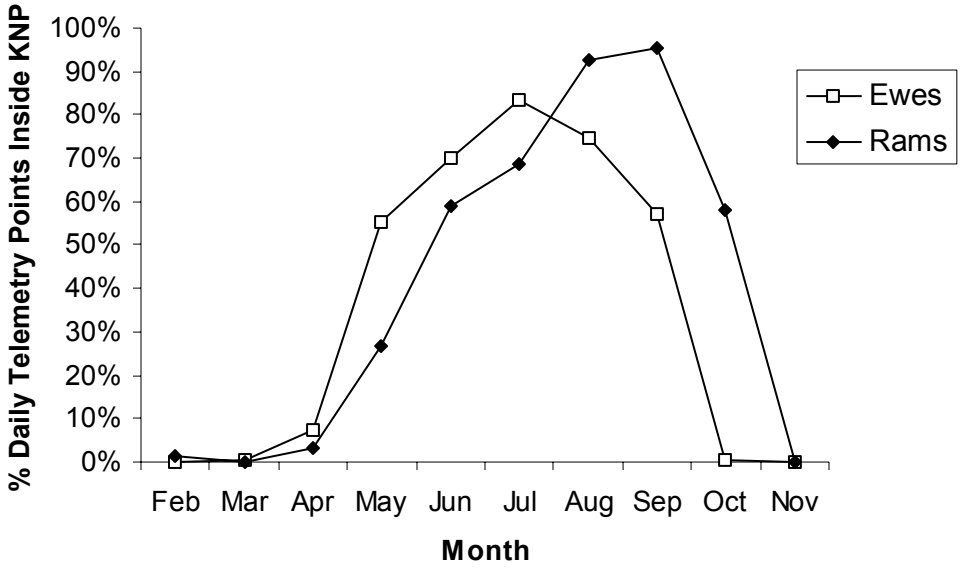

Figure 22. Percent of sheep daily telemetry locations inside KNP by month and sex.

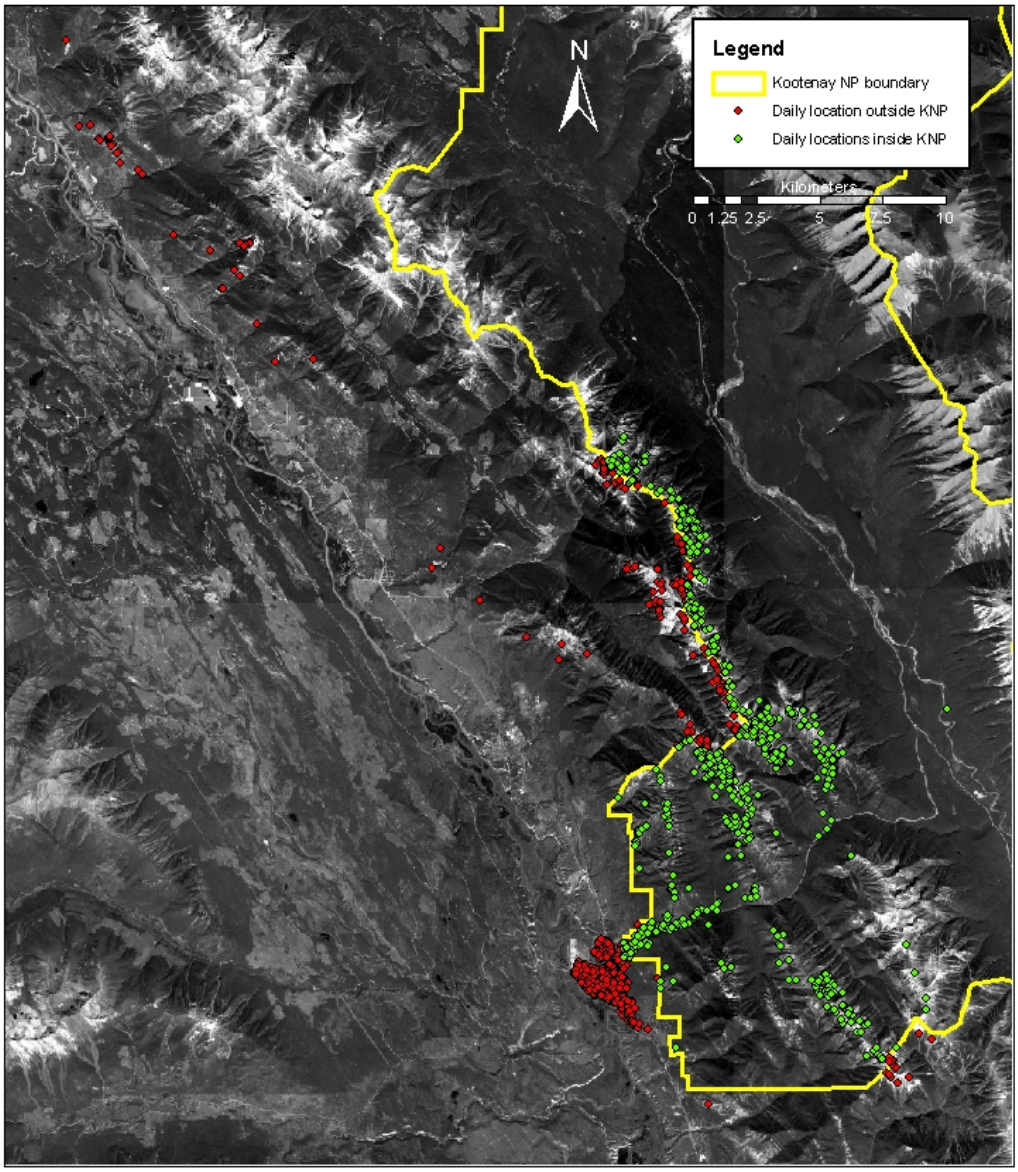

Figure 23. Sheep daily telemetry locations inside and outside KNP during the 2006 study year.

Response to Restoration of Winter Range

The Redstreak Grasslands Restoration Area (see Figures 1a and 25), a total area of 173 ha (Dibb 2006), was examined for the occurrence of telemetry points that would indicate use of this habitat by collared sheep in 2006. The restoration area comprises approximately 9.0% of the total winter range available to the Radium-Stoddart herd (Dibb 2006). In this analysis, the 'restoration area' includes the treated federal and provincial blocks, the Redstreak prescribed burn guard, and the area below the Redstreak Campground (see Figure 25). Only "daily" telemetry points, as defined in the previous section, were considered.

Six out of eight study animals were recorded using the restoration area this year, with rams using the area more often than ewes (see Table 6 and Figure 24). A total of 24 daily telemetry points were logged in the restoration area, with an average of 3.0 per animal (SD = 5.01 days, range = 0-15 days). Only 1.11% of daily telemetry points for all 2006 study animals occurred inside the restoration area. M404 recorded the greatest number of points within the restoration area of any collared sheep. The highest use of the area for both ewes and rams occurred during the period between April and June (Figure 24). No daily telemetry points were recorded in the provincial (eastern) block of the restoration area this year (Figure 25).

Table 6. Use of the restoration area by individual collared sheep in 2006

Sheep ID	Total daily locations	Total in Restoration Area	Percent
M002	274	4	1.46%
M404	264	15	5.68%
M405	275	1	0.36%
F402	266	0	0.00%
F403	273	1	0.37%
F407	271	1	0.37%
F410	266	0	0.00%
F415	272	2	0.74%
Total	**2161**	**24**	1.11%
Average	**270.1**	**3.0**	1.12%

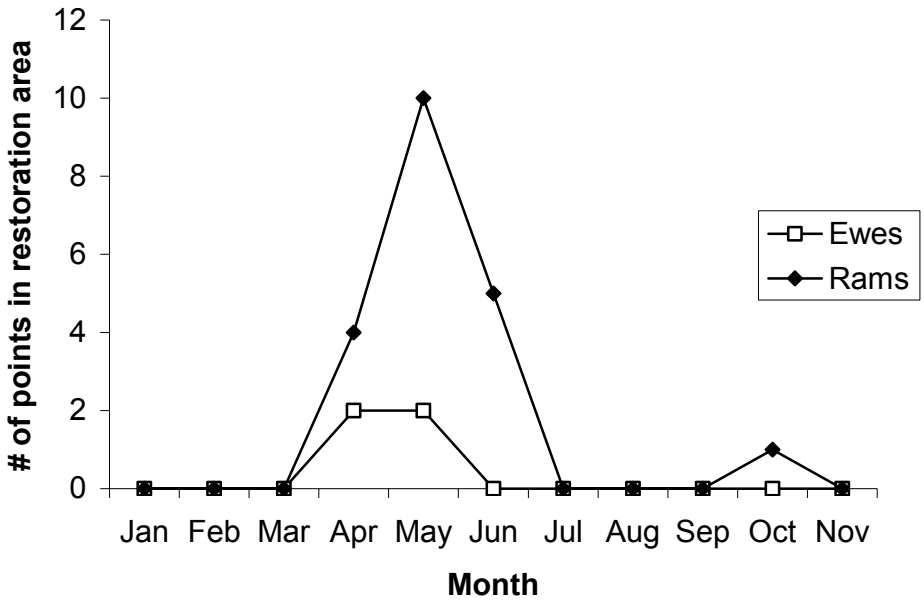

Figure 24. Use of restoration area by month and sex for collared sheep in 2006.

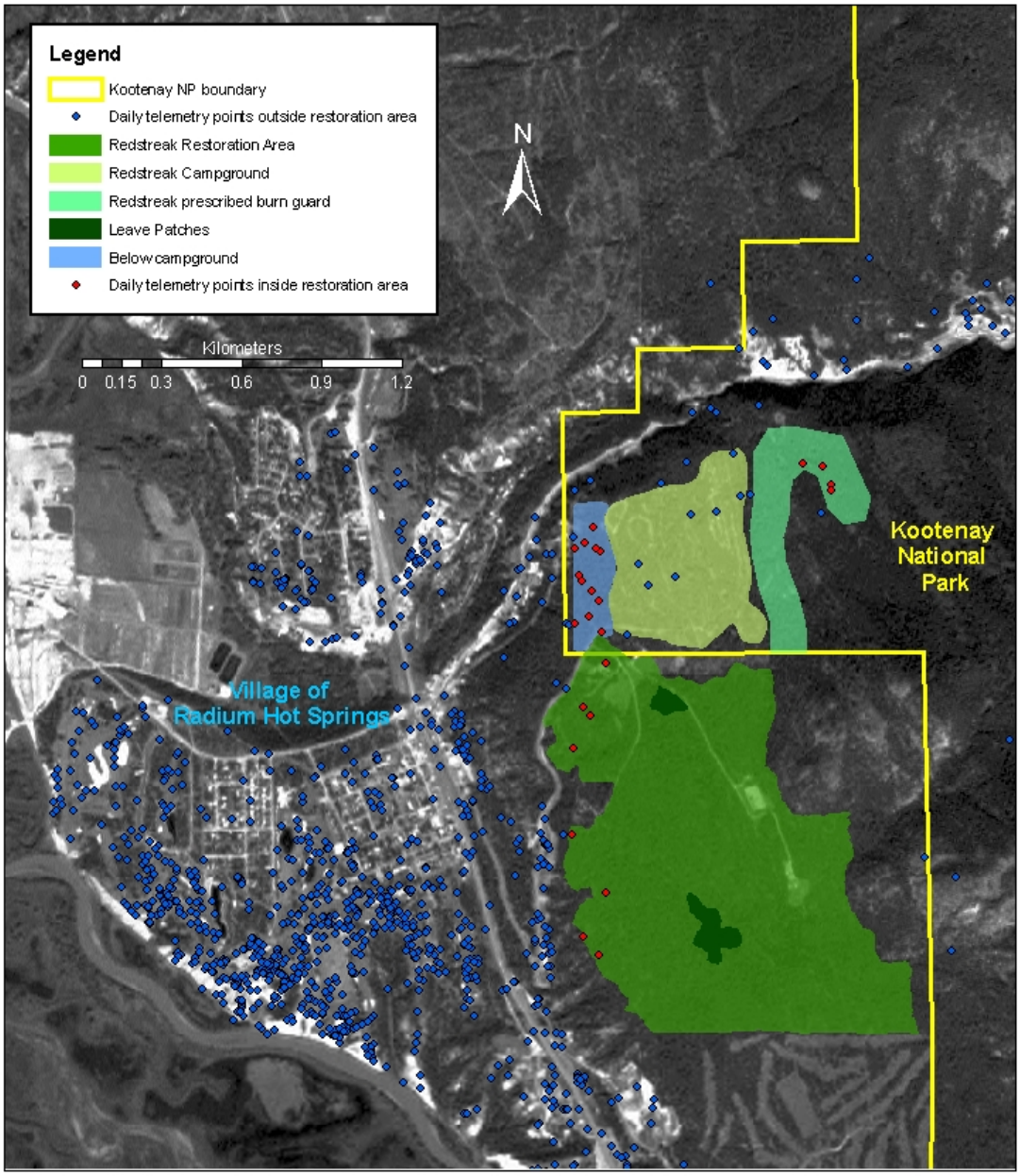

Figure 25. Daily telemetry points inside the restoration area in 2006.

DISCUSSION

GPS Collar Fix Success Rate

The fix success rate for GPS collars during the 2006 study year was 93.9%, while 89.9% of these successful fixes were three-dimensional. The proportion of 3D points collected by collars was the same as was obtained last year, while the overall fix success rate has increased from 92% in 2005 (Anderson 2006).

Mortality and Injuries

Highway strikes were by far the most commonly reported cause of death for Radium-Stoddart sheep this year. Other known causes of mortality included a fall, a bacterial pneumonia infection and a railway strike. A total of 16 sheep were reported killed between January and November 2006. There were no study animal mortalities in 2006; however, two of the collared rams suffered injuries that were likely sustained during combat and were unrelated to the collars. M404's collar was removed early to prevent further aggravation of his injured jaw.

Lamb Production and Lambing Areas

The number of lambs is expected to begin declining immediately subsequent to the lambing season, as bighorn sheep are subject to high mortality rates during the first year of life. Demarchi *et al.* (2000) estimate that annual lamb mortality may range between 40% and >90%, with the highest number of mortalities occurring in the first few weeks following parturition and during the winter. Therefore, there should be relatively fewer lambs in the spring (as they approach 1 year of age), after the overall proportion of lambs in the population has decreased. The results summarized previously reflect this expectation, with the relative proportion of lambs:ewes being less in the spring (35:100, for 2005 lambs approaching 1 year of age) relative to the fall (61:100, for 2006 lambs approximately six months of age). The lamb:ewe ratio for collared ewes (between 57:100 and 71:100) is roughly equivalent to the ratio for the population as a whole (61:100), based on counts of lambs born during the same year (i.e. lambs born in 2006, fall counts only).

Counts and Classification

The best daily and group counts (highest numbers with minimal unclassified animals) were made while sheep were concentrated and easily accessible on their winter range in Radium. Sheep on summer range are harder to count, since group sizes tend to be smaller and sheep are dispersed over less accessible high-elevation terrain. This pattern of count success has been

consistent for all study years since 2002. By fall 2006, estimated minimum size of the Radium-Stoddart herd was 140 individuals.

Use of Mineral Licks

Visits to the Sinclair mineral lick are easily observed from GPS collar data, since sheep are not known to visit that particular location for any other purpose but to lick minerals (Anderson 2006). Visits to the McKay salt shed are harder to confirm, since it lies on a sheep migration route to and from John McKay Ridge (Anderson 2006). Sheep may stop briefly to lick minerals before continuing on their migration; however they do not always remain at the site long enough for the collar to record a GPS location. Trips made to the McKay salt shed during seasonal migrations also do not exhibit the characteristic rapid elevation loss observed when sheep visit the Sinclair lick. Since visits to the McKay salt shed are harder to detect, they may have been underestimated in these results. Increased use of the salt shed in spring and late summer, but low use during the middle of summer (June and July; see Figure 7), may further indicate that opportune visits occur during seasonal migration periods.

Collared sheep visited mineral licks only during the spring and summer months (May-August). This finding is consistent with research on other ungulates suggesting that mineral deposits in the skeleton decline over the winter, when mineral content in forage is not sufficient to replenish these stores (Nikolaevski 1961 and Preobrazhenskii 1961, cited in Geist 1971). Sheep must therefore restore these mineral reserves in the spring by visiting licks. It makes sense that ewe-lamb groups would visit mineral licks more frequently than rams, as was found in this report, since ewe-lamb groups contain lactating and growing individuals that have greater energy demands (Geist 1971).

Visits to mineral licks, while necessary to maintain body condition, also pose some hazards to sheep survival. Minerals draw sheep close to busy highways, particularly in areas where salt is used to de-ice the pavement, so they are at higher risk of being hit by vehicles (Dibb 2006). Artificial de-icing salts may also contain toxic substances that could have health consequences for sheep consuming the salt, although this has not yet been investigated (Dibb 2006).

Home Ranges, Seasonal Ranges and Migratory/Dispersal Movements

On average, rams had slightly larger MCP and 90% kernel home ranges compared to ewes. This disparity may be actually be greater, however, since average ewe home ranges were likely overestimated due to an extensive northerly movement by F410. Summer range for both ewes and rams was the southern end of the Brisco Range, both within and outside the KNP

boundary. The ridges following the Kindersley-Sinclair trails, the Mt. Berland ridgeline, and the ridges along the park boundary between Mt. Crook and the Kindersley-Sinclair col were the most heavily used this summer. M405 was the only collared sheep to spend part of the summer in the more southerly Stanford Range.

The Sinclair Canyon and HWY 93S (west of McKay Creek) formed a migration corridor frequented by collared sheep before or after a major elevation change. This is not an ideal transitional range, however, as it is heavily forested on both sides and has high levels of traffic year-round. The restoration area will hopefully provide a safer and more natural transitional range for migrating sheep. Critical winter range continues to be centred on the Radium townsite, golf course, and surrounding areas. The Mile Hill was used more often by rams, whereas ewes tended to remain on the golf course and in southwest Radium for much of the winter.

No dispersal movements were noted for collared sheep from the Radium-Stoddart herd in 2006. Possible dispersal routes would be north, to a group of bighorns maintained near Golden, south to the Columbia Lake herd, or east to the Vermillion range, which once supported a bighorn population (Anderson 2006). Although no collared sheep visited the Stoddart Creek area this year, a group of 11 unmarked sheep were observed at this location on December 6th, indicating its continued use as bighorn winter range.

Use of Terrain

On average, ewes tended to begin their migration to high elevation summer range about one month earlier than rams (May and June, respectively). This results from the need for ewes to find suitable lambing terrain in the spring, preferably steep and inaccessible to predators. Although rams began their spring migration later, their fall migration back to low elevation winter terrain was also delayed by approximately one month compared to that of ewes. Ewes and rams share much of the same low elevation winter range. Spring and fall migrations were rapid for both male and female sheep, usually taking only a few days to complete.

Domestic Sheep Issues

Proximity of domestic sheep to bighorn populations is of concern because of the possibility of disease transmission between the two species. Wild sheep do not have any natural resistance to the pathogens of domestic sheep, and therefore could be severely affected if contact between wild and domestic populations were to occur. Pathogens that may be transferred between domestic and wild sheep include bacteria of the genus *Pasteurella*, which are commonly found in healthy domestic sheep but often cause fatal pneumonia in bighorns (Demarchi *et al.* 2000).

The Firlands ranch near Radium poses the greatest threat to the Radium-Stoddart herd, since the vast majority of bighorn GPS points recorded near domestic sheep were within the 5 km buffer zone surrounding this site. However, the Columbia River runs between the Firlands ranch and the village of Radium, serving as a seasonal barrier between wild and domestic sheep populations. While the river presents an effective barrier against disease transmission for the majority of the year, when it freezes in the winter there is nothing to stop contact between wild sheep and domestic stock at the Firlands ranch. If disease transmission did occur at this site, it has the potential to spread extremely rapidly, since nearby bighorn sheep would be heavily concentrated on a small area of winter range.

At the Spillimacheen and Edgewater sites, most of the GPS points located within the buffers were recorded by a single animal (F410). Despite this, these sites are still of relatively high concern for disease transmission, since one infected animal has the potential to spread a pathogen throughout the entire herd. Even though F410 was far outside the typical summer range when she approached these two ranches, she soon returned to areas frequented by other bighorn sheep and presumably interacted with them (i.e. the potential for disease transmission exists). At the Shuswap Creek site, only two points were recorded by a single collar (M405) within the 5 km buffer. This data suggests, however, that unmarked bighorns from the Radium-Stoddart herd may also have approached this area and interacted with domestic sheep.

Use of Kootenay National Park Versus Out of Park Areas

Peak use of KNP during 2006 occurred when sheep were on summer range, a finding that is consistent with data from past study years (Anderson 2006, Dibb 2006). The highest use of KNP by ewes was in July, immediately following the lambing season. This suggests that areas within KNP provide important forage, mineral licks, escape terrain, and other necessary resources to ewe-lamb nursery herds. Peak use of KNP was later for males than females, occurring in September rather than in mid-summer. As in prior study years, high use of KNP by rams coincides with the general open hunting season (full-curl rams only) between September 10th and October 25th (Fish and Wildlife Branch 2006). Rams may concentrate their range inside the park during this time, as they cannot be legally hunted within its boundaries.

Response to Restoration of Winter Range

Use of the restoration area has declined this year compared to previous study years (except for 2002, before the restoration work had been completed). Only 1.11% of all daily telemetry locations were inside the restoration area, compared to 3.2% in 2003 and 8.9% in 2004.

Rams recorded the majority of points within the restoration area this year, primarily during the period between April and June. Females rarely used the restoration area in 2006, which seems to be consistent with findings from other years. Continued monitoring of the restoration area will be necessary to establish a long-term trend of its use by Radium-Stoddart sheep. There may be some annual fluctuations in the degree to which this habitat is utilized by bighorns, due to climatic variation and other factors. Future treatment of surrounding areas may increase the frequency of sheep use for all restored habitat.

CONCLUSION

The 2006 collared sheep behaved similarly to sheep in previous study years. This year was the first in which there were no study animal mortalities; however, highway strikes continue to be a major source of mortality for the Radium-Stoddart herd. F410's use of the Spillimacheen area for her lambing range was unusual, although use of this area as a lambing site was also documented for F010, an ewe that was collared in 2002 (Dibb 2006). Lamb production by collared females was down slightly from last year, but still within the estimated range for the population as a whole. The southern Brisco Range was heavily used by both rams and ewes during the summer; however, M405 also spent some time in the Stanford Range. Use of the restoration area by collared sheep appeared to decline slightly this year, although this may represent a short-term fluctuation. Developed areas in the village of Radium, as well as the adjacent golf course and the Mile Hill, continue to serve as primary winter range.

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APPENDIX I: SUMMARY ACCOUNTS OF INDIVIDUAL STUDY ANIMALS

M002

M002 was captured and collared behind the Radium Village office on January 30th, 2006. He spent the winter and spring months in Radium and the surrounding area, including the Mile Hill, the golf course, and Radium north (see Figure 10). M002 began his spring migration on June 14th, following HWY 93S along Sinclair Canyon before turning northward near Kimpton Creek. He reached the area around the Kindersley-Sinclair col on June 18th. M002 then followed the KNP boundary northward. He spent 4 days (June 21st-24th) zig-zagging north to south along a ridge SE of Mt. Crook, making 3 trips back and forth in total. He then continued traveling NW along the park boundary until reaching Mt. Crook on the evening of June 24th. M002 spent most of the summer on the eastern slopes of ridgelines between Mt. Kindersley and just NW of Mt. Crook. He made one visit to low elevation during the summer (between July 17th and 23rd), at which time he probably visited both the Sinclair mineral lick and the McKay salt shed. During this foray, he made his way southward along the park boundary and then the ridgeline above the upper Kindersley trail, before reaching HWY 93 S near the Sinclair lick around noon on July 18th. M002 then continued SW to the McKay Creek compound and arrived at the hot pools on July 19th. He returned to the ridges north of Mt. Kindersley by July 23rd, where he spent the remainder of the summer until mid-October. M002 began his fall migration on October 19th. He headed almost due south and reached the entrance to the McKay Creek compound at on October 21st. He then followed Sinclair Creek SW and reached the admin. road at on October 22nd. M002 spent the rest of the fall on the eastern fairways of the golf course and in Radium village. His collar was removed on November 1st at the golf course.

M404

M404 was captured on the Springs golf course on January 31st, 2006. He spent the winter and spring in Radium village and the surrounding areas. During this time, he made one trip NE to the cliffs in Sinclair Canyon on February 18th. In May, M404 spent time in the areas around Redstreak, KNP West Gate, eastern Radium, and the Mile Hill. He began migrating northward to summer range on June 5th. M404's spring migration route roughly followed the boundary of KNP. He arrived at the ridges just W of the Kindersley-Sinclair col by June 7th, the eastern slopes just N of Mt. Kindersley by June 20th, and the area around Mt. Crook by the evening of June 24th. M404 spent the rest of the summer and early fall in the area between Mt. Kindersley and the ridgelines NW of Mt. Crook. He made one visit to the mineral licks at both Sinclair and McKay between July 17th and 23rd. M404 followed the same path and timeline as previously described for M002 during the trip southward to the mineral licks. Presumably M002 and M404 were part of the same ram group at this time. M404 began his fall migration from high elevation summer range on the

afternoon of October 8th. His migration route again followed the KNP boundary. M404 reached HWY 93 S just E of the hot pools on October 13th. He then made a very rapid trip NW, arriving in an area just north of Edgewater late in the evening of the same day. M404 had returned to Redstreak Mountain about 3 hours after this and spent time around the Redstreak Campground from October 14th-17th. He logged 3 points on the northwest edge of the golf course before moving back up Sinclair Canyon and arriving at Radium Lodge on the morning of October 18th. His collar was removed on October 19th behind the Radium Lodge, due to a recent jaw injury.

M405

M405 was captured on the Springs golf course on January 31st, 2006. He spent the winter and early spring in Radium village and the surrounding areas. During this time, he made one trip to the Stoddart Creek area between the evening of April 15th and the morning of April 16th. On May 23rd, M405 headed east toward Redstreak Mountain from his winter range on the Mile Hill. He then traversed a small northerly loop just east of the Redstreak Restoration area before returning to his original location on Redstreak Mountain late on May 24th. M405 then moved SE to Dry Gulch on May 25th but had returned to the motel strip in Radium by early May 26th. He continued following HWY 93S through Sinclair Canyon and logged a point at the McKay compound entrance on the morning of May 27th. From there he turned SE and followed the eastern slopes of the Stanford Range to the park boundary near Kimpton Pass, where he arrived on June 4th. M405 spent most of June in the southern Stanford Range and then returned to the McKay compound on June 26th by back-tracking along the same route he had used earlier. He followed HWY 93S back down Sinclair Canyon and had returned to the Mile Hill by the evening of June 28th. On July 4th, M405 again left the Mile Hill and headed east to Redstreak Mountain, which he reached by the evening of July 5th. After spending a few days in this area, he headed back to the northern end of the Stanford Range on July 8th. He repeated his earlier SE route down the Stanford Range and arrived at Kimpton Pass on July 12th. On July 21st, M405 left this area and went north to visit the Sinclair mineral lick, where he arrived around noon on July 26th. He spent the next few days traveling north along KNP's western boundary before reaching Mt. Kindersley on July 30th. Until late August, M405 moved along the ridges between Mt. Kindersley and Mt. Crook. He began moving south from this area on August 22nd, again following the park boundary until turning east back to the Stanford Range. M405 followed the Stanford Range SE for the third time and arrived at the park boundary south of Kimpton Pass on September 2nd. He moved back up the Stanford Range from this area on September 10th. M405 remained in a concentrated area in the mid-northern end of the Stanford Range for the rest of September and most of October. He began his fall migration on October 18th, when he left the Stanford Range and headed NW to Sinclair Canyon. He reached the McKay compound by on October 22nd and followed HWY 93S to Radium village, where he arrived by the evening of October 25th. M405

spent the remainder of the fall in Radium and on the golf course. His collar was removed on November 2nd in residential Radium, at the corner of Pioneer Ave. and McKay Street.

F402

F402 was captured on the Springs golf course on February 1st, 2006. She spent the winter in Radium and the surrounding areas, during which time she made one visit to the hot pools between April 8th and 13th. F402 began her spring migration around midday on May 1st, when she left Radium and moved NE up Sinclair Canyon to the hot pools. She turned north from the hot pools on May 3rd and continued to her lambing range just SW of Mt. Berland. F402 remained at this general location from May 6-14th, when she probably had her lamb. She spent the remainder of the summer on the ridgelines that run alongside the upper and lower Kindersley-Sinclair trail, and the ridges between Mt. Kindersley and the Kindersley-Sinclair col. She also spent time on the ridge south of Nixon Creek that runs parallel to the Kootenay River. During this period, F402 made two separate trips to the Sinclair mineral lick, one on July 1st and another on July 11th. She also made another trip southward, this time to the hot pools, between July 31st and August 2nd. F402 began her fall migration from summer to winter range on the morning of September 13th. She reached the hot pool overflow lot very late the same day. She then continued moving along HWY 93S, through Sinclair Canyon, and arrived in Radium on the evening of September 17th. F402 spent the rest of the fall in Radium and the surrounding areas. Her collar was removed on November 1st at the golf course.

F403

F403 was captured on the Springs golf course on January 30th, 2006. She spent the winter in Radium and on the golf course. During this time, F403 made two trips to the cliffs above HWY 93S in Sinclair Canyon, one on February 27th and one on March 1st. Her movements shifted eastward at the beginning of May, with points collected between Radium and the hot pools in Sinclair Canyon. On May 6th, F403 left the hot pools and traveled north to the ridgeline directly east of Mt. Berland. She turned south later the same day and was back in Radium on the morning of May 7th. Over the next week, points were again logged between Radium and the hot pools. F403 left on her spring migration from the Redstreak Campground at on the morning of May 13th. She arrived on the slopes just SW of the Kindersley-Sinclair col around midday on May 14th. From May 14th-16th, she moved back-and forth on an east-west trajectory between this location and Mt. Berland two times. No definitive lambing range is indicated, since F403 probably did not have a lamb this year. If she did have a lamb, it is likely she lost soon after birth. F403 spent the rest of the summer on the ridges along the KNP boundary, between the Kindersley-Sinclair col and an area just north of Mt. Crook. She also spent time on the ridgelines running parallel to the upper and lower Kindersley-Sinclair trails. During her time on summer range, F403 made two

trips to the Sinclair mineral lick, one on the evening of June 23rd and another the morning of July 6th. She began her fall migration from the Kindersley-Sinclair col on September 5th and may have visited the McKay salt shed on September 6th as she traveled south. She arrived in Radium early in the afternoon of September 7th. Before settling on winter range in the village and on the golf course, F403 made two trips from Radium to the hot pools and back. Her collar was removed on November 1st at the golf course.

F407

F407 was captured northeast of Radium Elementary on January 31st, 2006. She spent the winter in Radium and the surrounding areas. F407 began her spring migration early on May 16th and left Radium to head NE via the admin. road and Redstreak Campground. She arrived at HWY 93S, just east of the hot pools, by the late hours of May 17th. She then headed north and reached her (possible) lambing range east of Mt. Berland on the afternoon of May 18th. If F407 did have a lamb, it would have been born in this area, since she remained there until June 2nd. She then continued north, arriving at the KNP boundary near the Kindersley-Sinclair col on June 8th. F407 spent the rest of the summer on the ridgelines running parallel to the Kindersley-Sinclair trail and on the ridges along the western park boundary between Mt. Kindersley and the Kindersley-Sinclair col. Like F402; F407's summer range also included the ridgeline parallel to the Kootenay River and south of Nixon Creek. During the summer, F407 made two trips the Sinclair mineral lick, one on July 19 and another on August 27th. She also made two other short-term visits to an area south of the Sinclair lick on July 3rd and 8th. These points may represent further trips to the mineral lick, but cannot be confirmed as such, since the collar did not log any points at the lick itself. F407 also made a brief excursion to the McKay compound area on July 30th, possibly to lick minerals at the salt shed. She began her fall migration on September 28th from the ridge directly west of the Kindersley-Sinclair col. Following this ridgeline south next to the lower Kindersley-Sinclair trail, she arrived at HWY 93S near the Iron Gates Tunnel late on Sept 30th. F407 then continued west along the highway and through Sinclair Canyon, eventually ending up on the golf course late on October 1st. She spent the rest of the winter on the golf course and in the village of Radium. Her collar was removed on November 1st at the golf course.

F410

F410 was captured on the Springs golf course on February 1st, 2006. She spent the rest of the winter in Radium and the surrounding areas. During this time, her collar also logged two points in the Redstreak Campground area, one each on April 27th and 29th. F410 began her spring migration on the morning of May 10th. She left Radium and followed the western boundary of KNP northward, reaching the slopes directly east of Edgewater by early evening on May 11th. She then turned NW and followed a route parallel to the Columbia River and HWY 95. F410

arrived just east of Brisco on May 15th and continued to move NW. On May 18th, she came to the cliffs directly NE of Spillimacheen and had turned N from here by May 20th. By late on May 21st, F410 had reached the southern end of the Beaverfoot Range, just east of Harrogate. She then turned around and retraced her route back toward Spillimacheen, arriving NE of this community on May 22nd. F410 remained in this area and probably had her lamb there between May 30th and June 2nd. She left on June 5th and retraced her original spring migration route, this time heading SE. After spending June 10th-18th on the slopes west of Mt. Norman near the southern end of the Brisco range, F410 continued SE and arrived just north of Edgewater on June 22nd. From here, she turned east and headed toward Mt. Kindersley, which she reached by early morning on June 26th. She spent the rest of the summer within KNP, on the ridges running north to south between Mt. Kindersley and HWY 93S. The majority of points logged during this time occurred near the Kindersley-Sinclair col and on the ridge parallel to the lower Kindersley-Sinclair trail. F410 made two trips to the McKay salt shed, one on July 12th and another on August 15th. It is possible she may also have visited the Sinclair lick on July 4th. F410 began her fall migration from the Kindersley-Sinclair col on September 12th. She headed due south and arrived at HWY 93S, just E of the McKay compound, by September 13th. She continued SW down Sinclair Canyon and reached Radium by evening on September 17th. F410 spent the remainder of the fall in Radium and on the golf course. Her collar was removed on November 1st at the golf course.

F411

F411 was captured at the entrance to the Springs golf course on February 1st, 2006. The collar malfunctioned when it was put on and was unable to log any GPS points. Telemetry observations indicated that she spent the rest of the winter on the golf course and in the village of Radium. The collar was removed on March 14th at the golf course.

F415

F415 was captured on the Springs golf course on January 31, 2006. She wintered in Radium and the surrounding areas, during which time she made three short trips north to Sinclair Canyon. On April 12th and 28th, she traveled to an area just north of the hot pools, and on March 1st she logged points in Sinclair Canyon just west of the hot pools. F415 left Radium on her spring migration on May 1st. She moved up Sinclair Canyon and arrived at the hot pools late on May 4th. From here, she headed NE to the southern end of a ridgeline due east of the McKay compound, where she arrived on the morning of May 5th. F415 then returned south and was back at the hot pools by late evening of the same day. On May 6th, she headed N from Sinclair Canyon and spent May 7th-13th on the slopes S of Mt. Berland and N of the hot pools. This area was probably her 2006 lambing range. After having her lamb, F415 returned to the hot pools late on May 16th. After spending several days in the area, she left the hot pools again on May 21st and headed NE.

Between May 21st and 24th, she logged points on the southern end of the ridge directly east of McKay, which she had visited earlier in the month. She then headed north along this ridgeline. F415 spent the remainder of the summer on the ridges between Mt. Kindersley and HWY 93S. She logged the majority of points during this time on the two ridgelines paralleling the upper and lower Kindersley-Sinclair trails. An out-lying point was logged east of the Kootenay River on the afternoon of July 23rd. Although it seems unlikely that F415 could have traveled this far in such a short time, or was able to cross the river, the point is 3D and has a relatively low PDOP value (6.0). She therefore may have been in the general vicinity of this point, but was probably on the western side of the river. During her time on summer range, F415 made numerous visits to both the Sinclair and McKay mineral licks. She visited the McKay salt shed twice (August 8th and August 29th) and the Sinclair lick three times (June 16th, June 22nd, and July 4th). It is possible she also visited the Sinclair lick a fourth time on June 18th. F415 began her fall migration on September 21st from an area directly west of the Kindersley-Sinclair col. She traveled south down the Mt. Berland ridgeline and arrived at Sinclair Canyon on the morning of September 23rd. She then turned SW and was at the golf course by evening of the same day. F415 spent the rest of the fall on the golf course and in the village of Radium. Her collar was removed on November 1st at the golf course.

APPENDIX II: TELEMETRY SUMMARY

M002 "Mo"


Morgan Anderson


Ross MacDonald

30-Jan-06	Collared behind Radium Village office
Early-mid-Feb	Seen four times at golf course
16-Feb-06	Seen in a group on Mile Hill with M404 and M405
Late-Feb	Seen twice with M405 on slopes north of 4-way stop
To mid-Mar	Seen on golf course 7 times
Late-Mar-early-Apr	Seen six times on Mile Hill, often with other collared rams
19-Apr-06	Seen north of 4-way stop in RV Park
27-Apr-06	Seen at West Gate to KNP
8-May-06	Seen on Admin. Road
To early June	Signal heard in vicinity of West Gate and hot pools area
Early June	Seen three times at Redstreak campground and in Radium
14-June-06	Seen at McKay Operations Centre
To mid July	Signal heard at various locations between Kootenay Viewpoint and Kootenay Crossing
Mid-late July	Seen four times near McKay and tunnel
To mid Oct	Signal heard at various locations between Kootenay Viewpoint and Kootenay Crossing
Late Oct	Signal heard at McKay and downtown Radium
1-Nov-06	Collar removed at golf course, near clubhouse

M002 was seen in groups of 2-117 sheep. The larger groups M002 was seen in consisted mainly of adult females and YOY, whereas smaller groups (2-31 sheep) tended to consist of mainly class II and III rams. He was seen with both other collared rams and all of the collared females. Collar function was checked 103 times, with only 1 indistinct signal (0.97% of all signals). M002 was seen 32 times after being collared on January 30, 2006 (including day of collar release).

M404


Nicole Obee


Ross MacDonald

31-Jan-06	Collared at Springs Golf Course, 15th fairway

Early-mid Feb	Seen four times at the golf course
To Mid Mar	Alternately seen on the Mile Hill and the golf course, five separate times
15-Mar-06	Seen in residential Radium
21-Mar-06	Seen on golf course with M002
To early Apr	Seen five times on Mile Hill; often with M002 and/or M405
19-Apr-06	Seen north of 4-way stop in RV park with M002 and M405
24-Apr-06	Seen on the Mile Hill
27-Apr-06	Seen at West Gate to KNP
8-May-06	Seen at Redstreak restoration area
To early June	Signal heard at hot pools, Redstreak campground, north of 4-way stop and at McKay compound
5-June-06	Seen with a ram group in canyon
To mid July	Signal heard at locations between McKay and Kootenay Crossing
Late July	Seen four times with M002; once below Kimpton, twice at the tunnel, and once near McKay
To mid Oct	Signal heard along HWY 93S between Kootenay viewpoint and Kootenay Crossing
18-Oct-06	Seen alone near Radium Lodge (swelling not yet apparent)
19-Oct-06	Collar removed near Radium Lodge due to a very large swelling under jaw; possible broken jaw sustained during combat with other rams
1-Nov-06	Seen at golf course entrance in ram group, still with swollen jaw; however exhibiting combat behaviour

Between February and May, M404 was seen alone and in groups of 2-117 sheep. M404 was seen both with large ewe/lamb groups (33-117 sheep) and more frequently with smaller (2-31) groups comprised mainly of class II, III, and some class 1b rams. He was seen with all other collared sheep. Collar function was checked 92 times, with only 1 signal failing to double-beep (1.09% of all signals). M404 was seen 28 times after being collared on January 31st (including and subsequent to day of collar release).

M405


Brianna Wright


Nicole Obee

31-Jan-06	Collared at Springs Golf Course Academy
Early to mid Feb	Seen four times at golf course
Feb-16	Seen on the Mile Hill in a ram group with M404 and M002
To 22-Feb	Seen twice north of the 4-way stop in ram groups with M002
To 15-Mar	Seen six times on golf course
To 5-Apr	Seen six times in ram groups near the Mile Hill lookout
10-Apr-06	Seen on front lawn of Admin. building in a small ram group
19-Apr-06	Seen north of 4-way stop with M002 and M404
27-Apr-06	Seen at West Gate with M002 and M404
8-May-06	Seen on admin. road
To early July	Signal heard near Mile Hill, West Gate, hot pools, McKay office, and old admin. building

To late Oct	Signal heard between McKay and Dolly Varden
23-Oct-06	Seen at side of highway near McKay with small ram group
27-Oct-06	Seen in Residential Radium at baseball diamond
2-Nov-06	Collar removed in Radium at Pioneer Ave. & McKay St.

M405 was seen alone and in groups of 4-117 sheep. On most occasions, M405 was seen in small groups (4-31) of class 1b, class II and class III rams. The few times he was sighted in larger groups, they tended to contain sheep of both sexes and most age classes. M405 was seen at least once with each of the other collared sheep. Collar function was checked 84 times. Three of these checks failed to give a double-beep (3.57% of all signals) and 1 check had an indistinct signal (1.19% of all signals). M405 was seen 26 times since he was collared on January 31st (including day of collar release).

F302

30-Jan-06	Collared at Springs Golf Course, 9th fairway
To late Feb	Seen five times on golf course
22-Feb-06	Seen in downtown Radium
27-Feb-06	Seen on Old Coach Road
To late Mar	Seen nine times on golf course
30-Mar-06	Seen north of 4-way stop
Early Apr	Seen three times in vicinity of downtown Radium
To Late May	Seen twice at hot pools, twice at golf course, and once at Redstreak Campground
6-Jun-06	Seen at McKay
To late Sep	Signal heard between West Gate and Dolly Varden
To 23-Oct-06	Seen five times on golf course
Late Oct	Seen twice in residential Radium
To 1-Dec-06	Seen six times on golf course
5-Dec-06	Seen alongside highway on motel strip in Radium
Mid Dec-06	Seen once on golf course

F302 was seen in groups of 13-117 sheep, mostly ewe/lamb groups. F302 was seen at least once with all of the other collared sheep. She did not appear to have a lamb this year. Collar function was checked 108 times, with 13 checks failing to double-beep (12.04% of all signals). F302 has been seen 41 times since she was first collared.

F402

1-Feb-06	Collared at Springs Golf Course, 14th fairway
To 27-Feb	Seen seven times at golf course and once south of the 4-way stop
To mid Mar	Seen six times on golf course
To 27-Apr-06	Seen eight times in Residential Radium, twice near 4-way stop, at once at Radium Lodge
To early Jun	Signal heard near bunkhouse, Redstreak, McKay and Radium Lodge
8-Jun-06	Seen near Iron Gates tunnel with lamb
To early Jul-06	Signal heard between McKay and Kootenay picnic site
To late Jul-06	Seen once at Sinclair trailhead, twice at Kindersley-Sinclair Col
To 2-Aug-06	Seen once at hot pools and twice at McKay
To late Aug	Signal heard between Kimpton trailhead and Dolly Varden
To 1-Sep-06	Mortality signal heard twice
15-Sep-06	Seen at hot pools overflow lot
To 1-Nov-06	Seen twelve times at golf course and four times in residential Radium
1-Nov-06	Collar removed at golf course, 2nd fairway

F402 was seen in groups of 9-117 sheep. She was usually seen in ewe/lamb groups, but was also sometimes seen in mixed groups in the spring and fall. F402 was seen with all other collared sheep. Her lamb survived at least until late September. Collar function was checked 109 times, with 5 checks failing to double-beep (4.59% of all signals) and 4 mortality signals (3.67% of all signals). F402 was seen 50 times since she was collared (including day of collar release).

F403

30-Jan-06	Collared at Springs Golf Course, 18th fairway
To 22-Feb-06	Seen six times at golf course
To 28-Feb-06	Seen twice in downtown Radium near 4-way stop
Mar-06	Seen seven times at golf course
To 11-May-06	Seen three times near downtown Radium, once on the golf course, once in residential Radium, and once by the bunkhouse

To early Jun	Signal heard north of Edgewater and at Spur Valley
To early Sep	Signal heard between West Gate and Kootenay Crossing
To 1-Nov-06	Seen eight times in residential Radium and seven times at the golf course
1-Nov-06	Collar removed at golf course, 1st fairway

F403 was seen in groups of 8-117 sheep. She spent time in ewe/lamb groups and in mixed groups of both sexes. F403 was seen with all of the other collared sheep. She does not appear to have lambed this year. Collar function was checked 104 times. Five of these checks gave an inactivity/mortality signal (4.81% of all signals), and 3 checks failed to double-beep (2.88% of all signals). F403 was seen 37 times since she was collared (including day of collar release).

F407

31-Jan-06	Collared northeast of Radium Elementary
To 20-Feb-06	Seen five times on golf course
Late Feb	Seen three times near downtown Radium
To 8-May-06	Seen nine times at golf course, and once each at residential Radium, downtown Radium, north of 4-way stop, Admin. Rd., and Redstreak restoration area
Mid May	Seen once at Admin. Rd. and once at McKay salt shed
To Mid Jul	Signal heard between West Gate and McLeod Meadows
Late Jul	Seen three times on Kindersley-Sinclair trail
To late Sep	Signal heard between McKay and McLeod Meadows
To 27-Oct-06	Seen six times on golf course
1-Nov-06	Collar removed at golf course, 1st fairway

F407 was seen in groups of 8-117 sheep, mainly ewe/lamb groups, but also some mixed groups in the spring and fall. She was seen with all of the other collared sheep. F407 probably did not have a lamb this year. Collar function was checked 95 times, with 6 checks failing to double-beep (6.32% of all signals). F407 was seen 34 times since she was collared (including day of collar release).

F408


Nicole Obee


Brianna Wright

1-Feb-06	Collared at Springs Golf Course, 1st hole
To 24-Apr-06	Seen fourteen times at golf course, four times in residential Radium, and twice in downtown Radium
To16-May-06	Seen twice in Sinclair Canyon below hot pools, once at McKay salt shed, and twice near admin. building
To 31-May-06	Signal heard between McKay and Kootenay picnic site
To 2-Aug-06	Seen twice near Iron Gates tunnel with lamb
To early Sep-06	Signal heard between Kindersley-Sinclair trailhead and Kootenay Crossing
7-Sep-06	Seen at Juniper trailhead
To late Nov-06	Seen twelve times at golf course and six times in residential Radium
24-Nov-06	Seen in Sinclair Canyon with lamb
To mid Dec-06	Seen four times at golf course
15-Dec-06	Seen on Admin. road near Radium Visitor's Centre

F408 was seen in groups of 4-117 sheep. She was observed in both ewe/lamb groups and mixed ram/ewe groups. F408 was seen with all other collared sheep and was confirmed to have a lamb this year. Collar function was checked 103 times, with 6 checks failing to double-beep (5.83% of signals). F408 has been seen 52 times since she was initially collared.

F410


Nicole Obee


Brianna Wright

1-Feb-06	Collared at Springs Golf Course, 10th fairway
To 27-Feb-06	Seen eight times at golf course
To 28-Mar-06	Seen five times at golf course, twice in downtown Radium, and once at the ball diamond
To 9-May-06	Seen three times at golf course, twice north of the 4-way stop, twice in residential Radium, and once downtown
To 27-Jun-06	Signal heard at West Gate, Spillimacheen, Brisco, and Edgewater

To late Jul-06	Signal heard between McKay and Dolly Varden
26-Jul-06	Seen below McKay office with lamb
To mid Sep-06	Signal heard between West Gate and McLeod Meadows
To 27-Oct-06	Seen ten times at golf course, once at West Gate, and once in residential Radium
1-Nov-06	Collar removed at golf course, 2nd fairway

F410 was seen in groups of 3-117 sheep. She was primarily seen in ewe/lamb groups, but was also observed in some mixed groups in the winter and fall. F410 was seen with all the other collared sheep and was confirmed to have a lamb this year. Collar function was checked 104 times, with 8 checks failing to double-beep (7.69% of signals) and 1 unclear signal (0.96% of signals). F410 was seen 38 times since being collared (including day of collar release).

F411

1-Feb-06	Collared at Springs Golf Course entrance
To mid Feb	Seen at six times at golf course, usually with at least one other collared female and sometimes collared males
22-Feb-06	Seen in downtown Radium with other collared females
To mid March	Seen four times on golf course, always in groups with other collared sheep
14-Mar-06	Collar released due to GPS malfunction

F411 was observed in relatively large mixed groups or ewe/lamb groups, ranging in size from 25-117 sheep. All sightings except one were at the golf course. Lamb confirmation was not possible since the collar was removed too early in the year. However, it seems likely that F411 did have a lamb, based on opportunistic observations after the collar had been removed (see above photographs). Collar function was checked 13 times. The collar failed to double-beep each time it was checked (i.e. failed to get any GPS fixes) due to damage sustained by the GPS antenna wire when the collar was first put on. The collar was removed early as a result of this malfunction. F411 was seen 12 times after the collar was first put on (including day of collar release).

F415


Nicole Obee


Brianna Wright

31-Jan-06	Collared at Springs Golf Course, 1st fairway
To 28-Feb-06	Seen seven times at golf course and three times in downtown Radium
To 24-Mar-06	Seen five times on golf course
To 27-Apr-06	Seen six times in Radium and once each at Sinclair Canyon, Radium Lodge, and north of the 4-way stop
To Early Sep-06	Signal heard between West Gate and Dolly Varden
8-Sep-06	Seen from Kindersley-Sinclair Col
To 27-Oct-06	Seen six times at golf course and four times in residential Radium
1-Nov-06	Collar removed at golf course, 2nd fairway

F415 was seen in groups of 3-117 sheep. She was mostly seen with ewe/lamb groups but was also observed in mixed ram/ewe groups in the late fall and winter months. F415 was seen with all the other collared sheep and did have a lamb this year. Collar function was check 103 times, with 4 checks failing to double-beep (3.88% of signals). F415 was seen 36 times since being collared (including day of collar release).

APPENDIX III: INDIVIDUAL STUDY ANIMAL MOVEMENTS

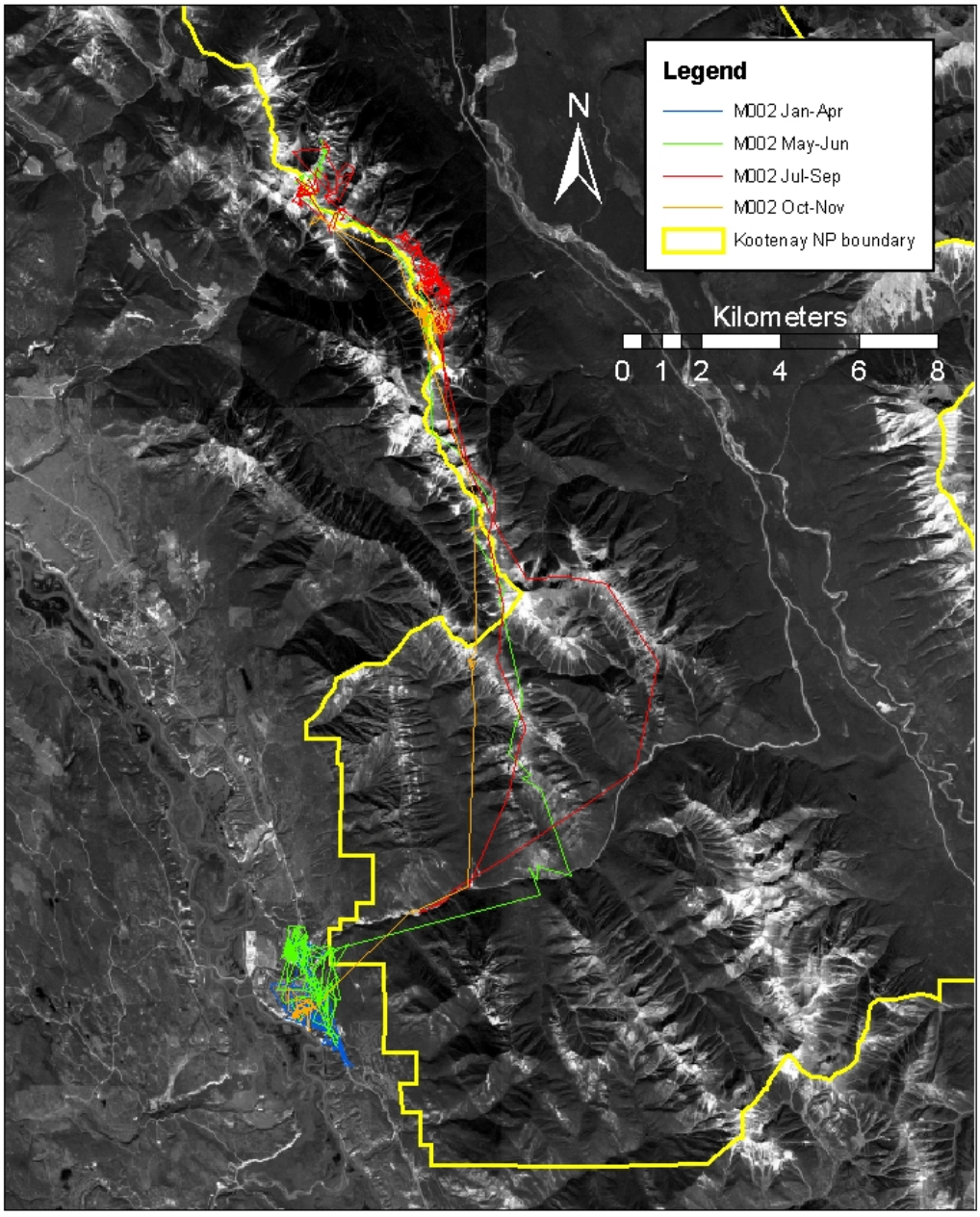

Figure 26. M002's 2006 movements by season.

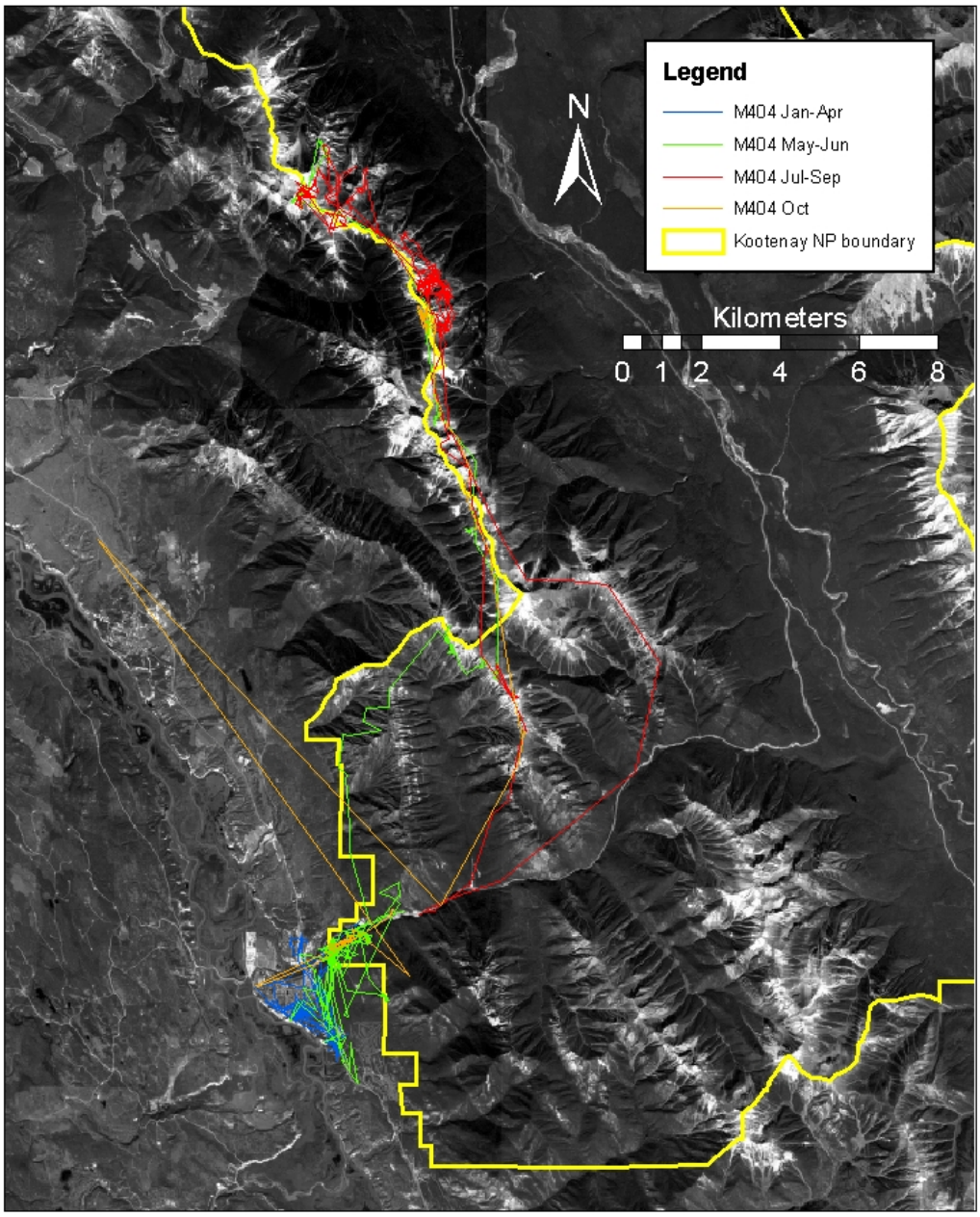

Figure 27. M404's 2006 movements by season.

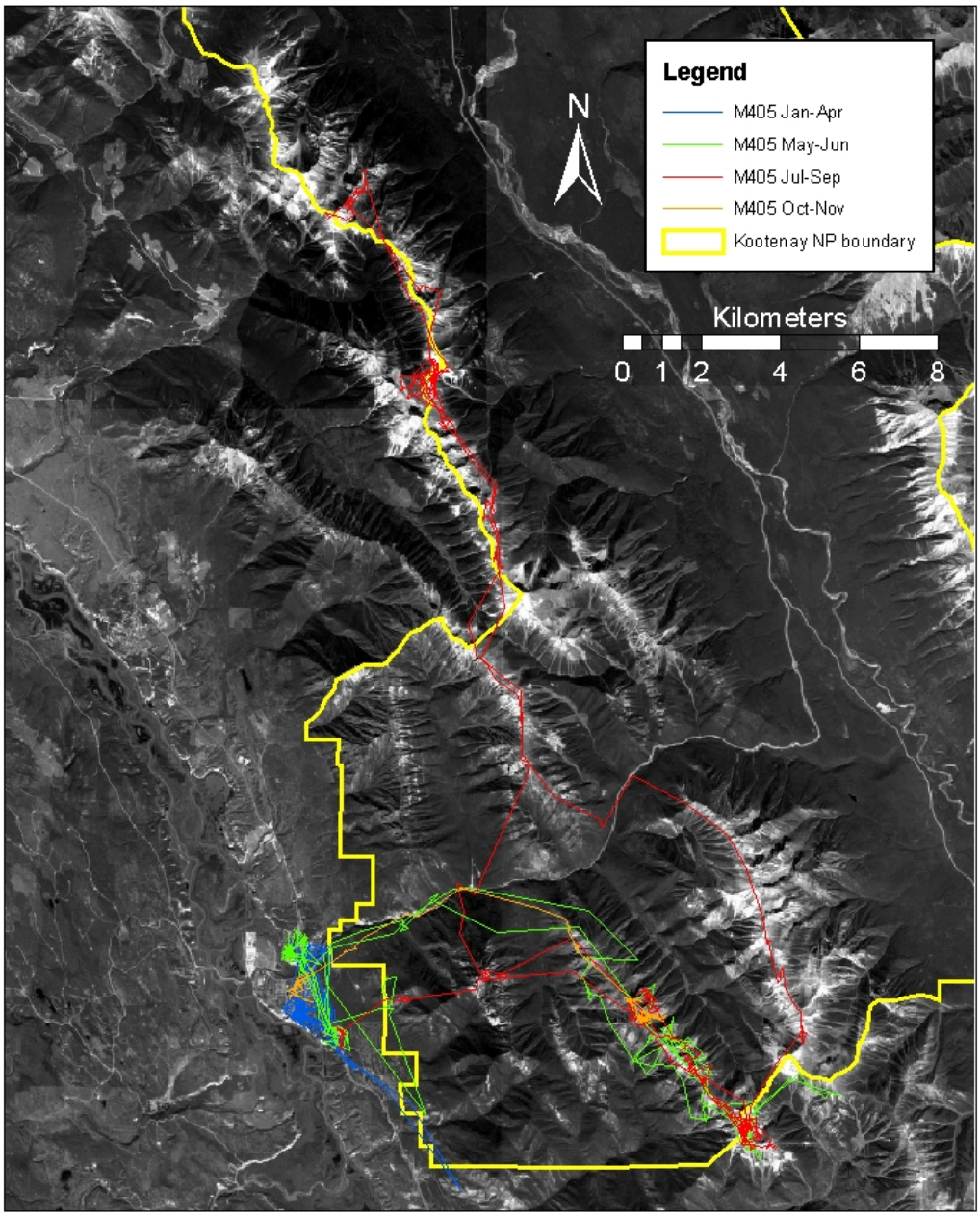

Figure 28. M405's 2006 movements by season.

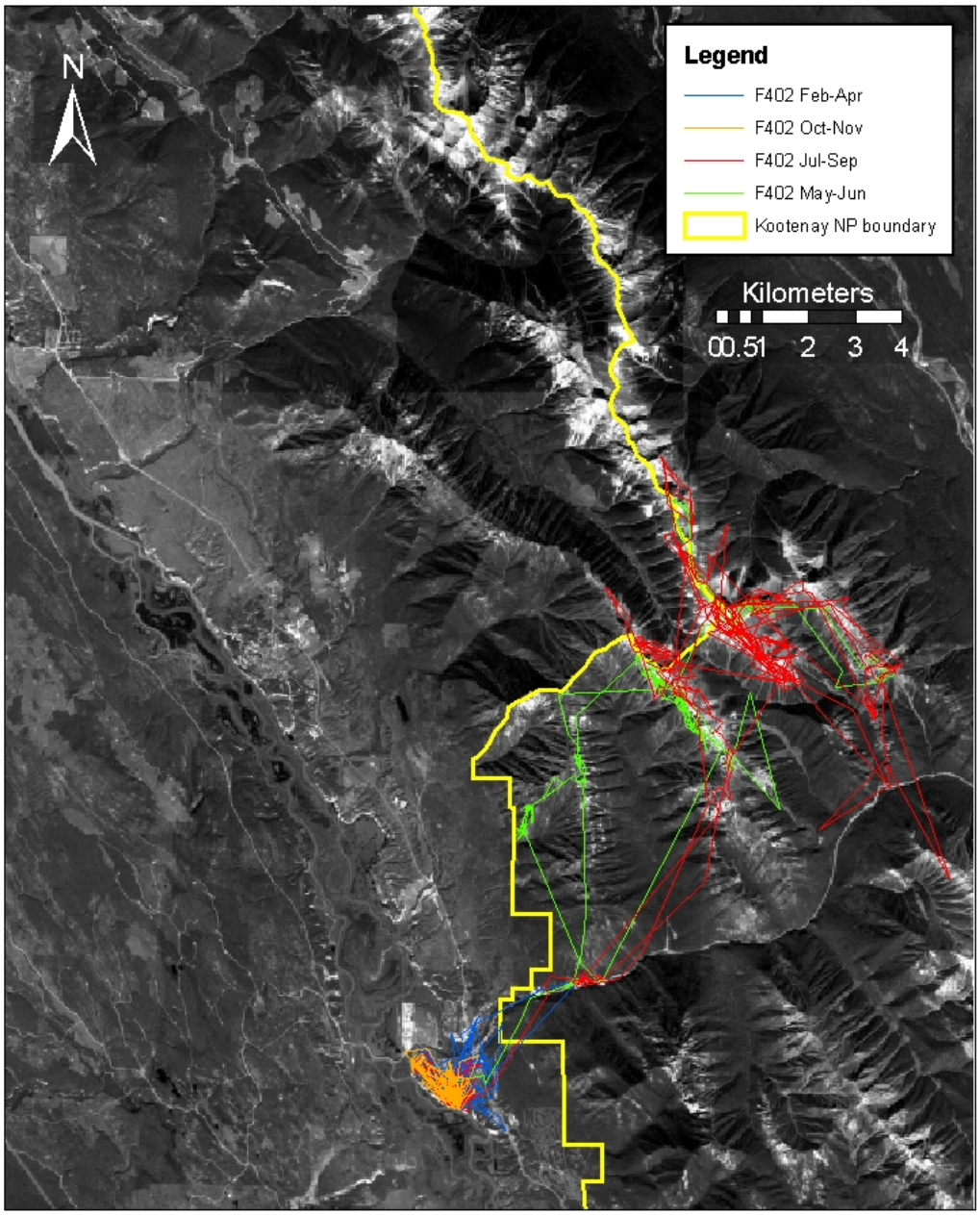

Figure 29. F402's 2006 movements by season.

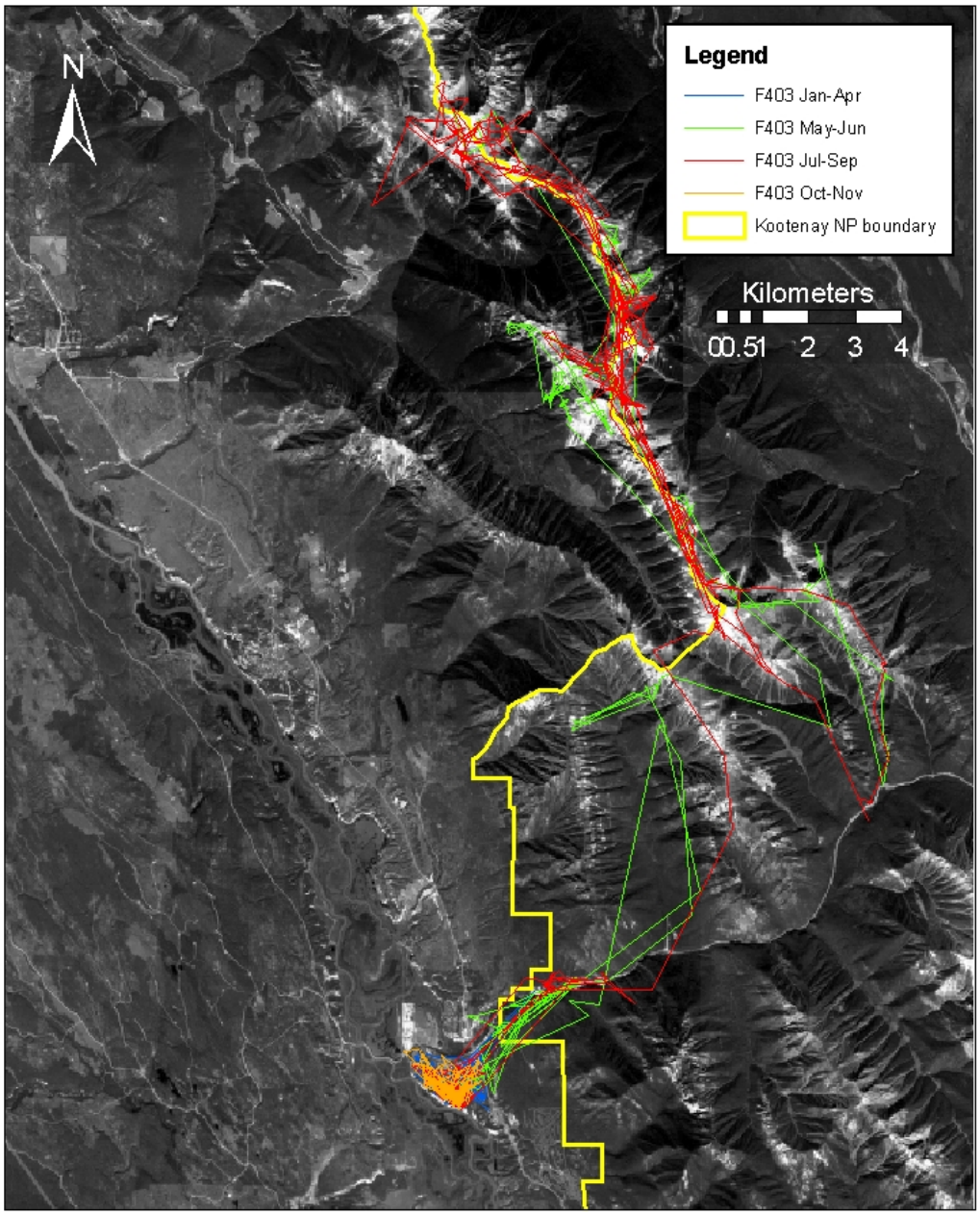

Figure 30. F403's 2006 movements by season.

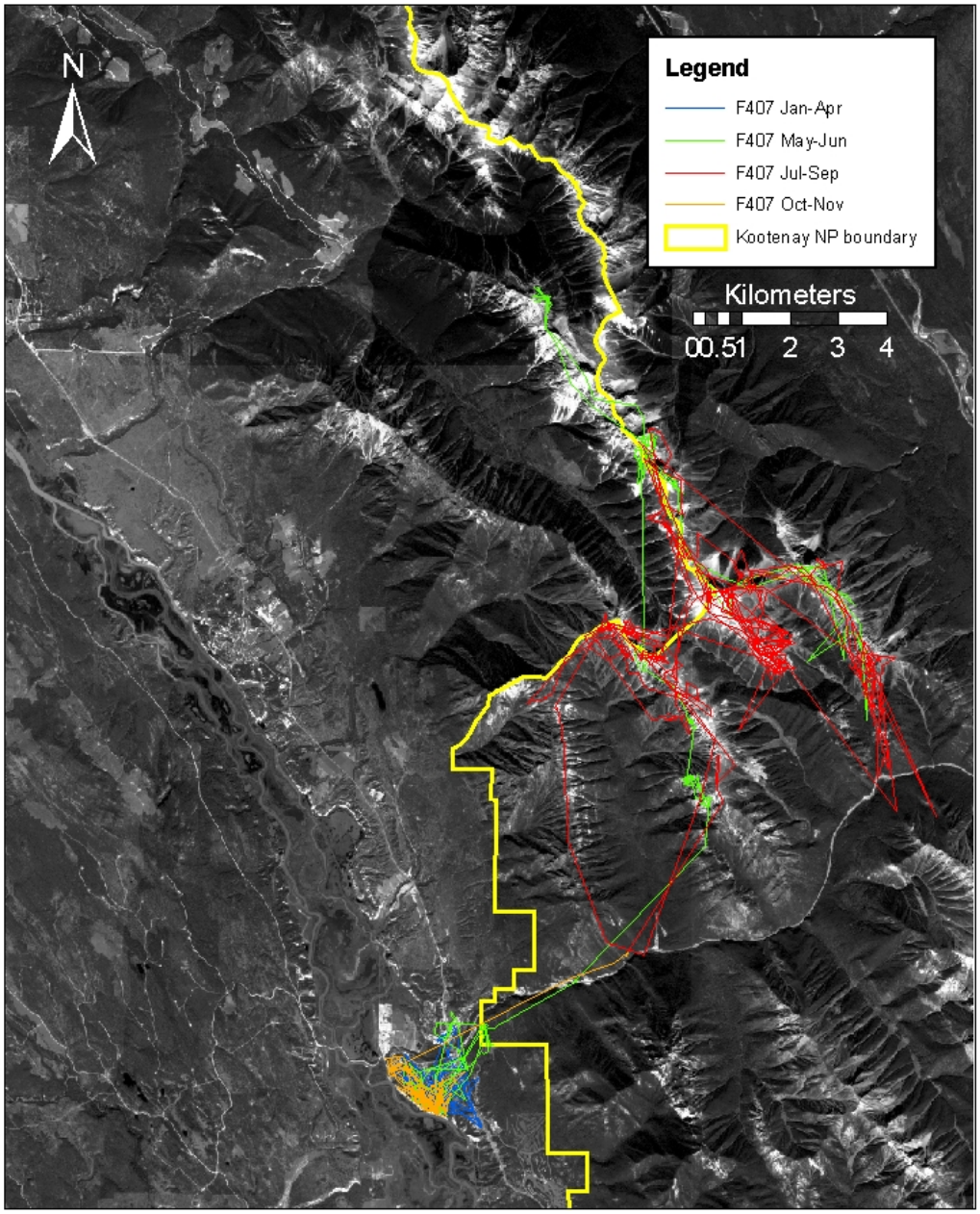

Figure 31. F407's 2006 movements by season.

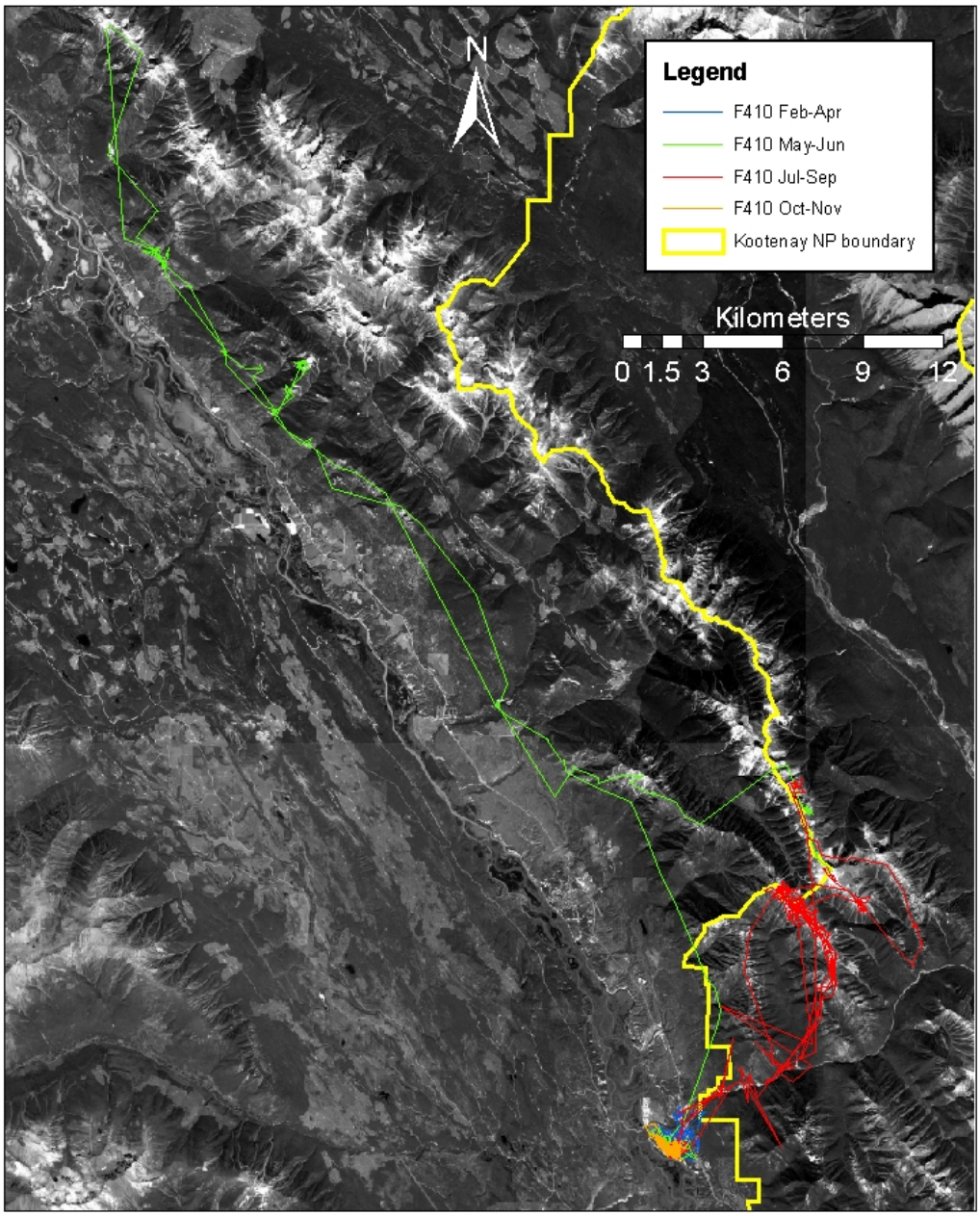

Figure 32. F410's 2006 movements by season.

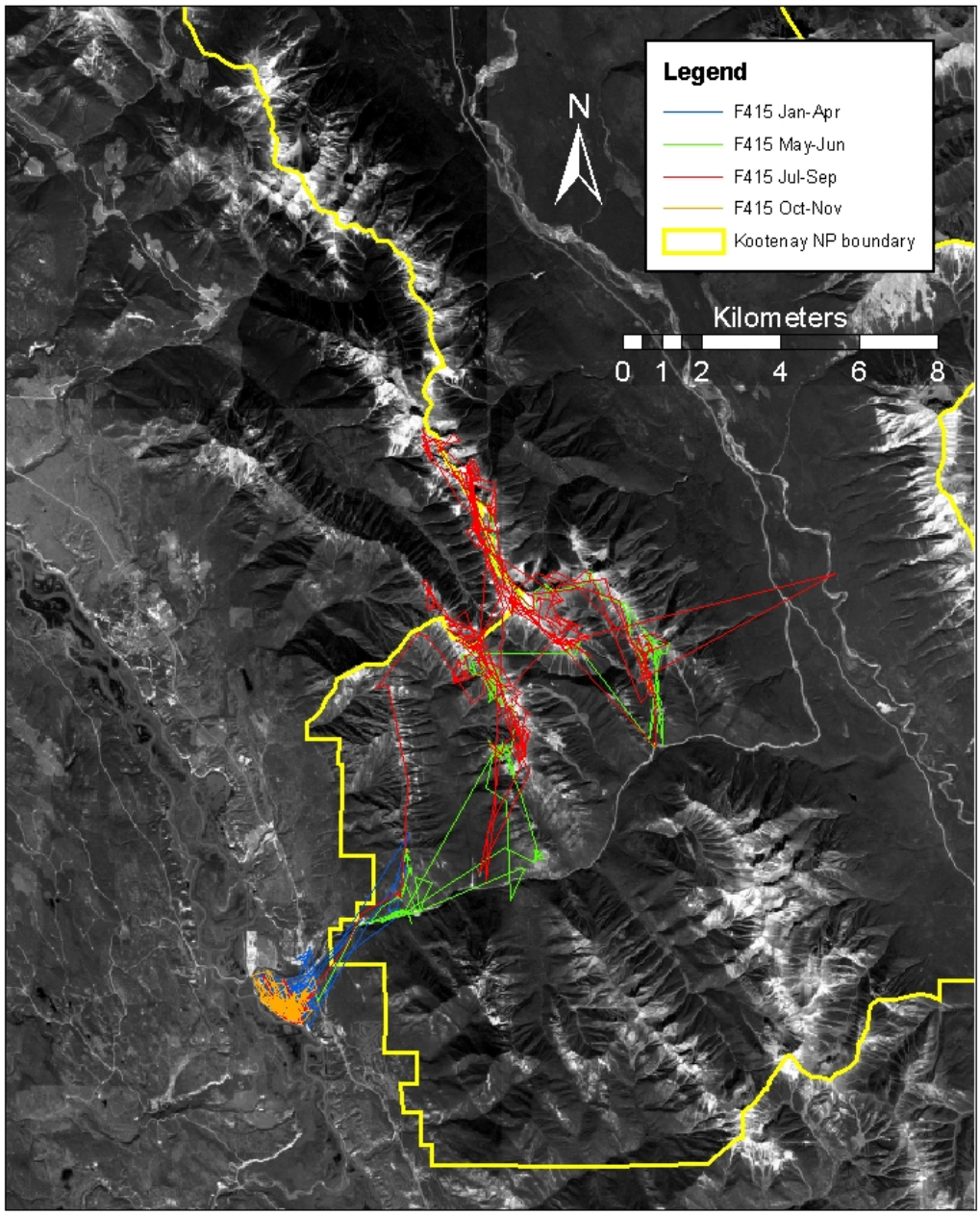

Figure 33. F415's 2006 movements by season.