# EFFECTS OF MILITARY OVERFLIGHTS ON HABITAT USE AND SELECTION BY FEMALE DALL'S SHEEP, YUKON-TANANA UPLANDS, ALASKA

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# EFFECTS OF MILITARY OVERFLIGHTS ON HABITAT USE AND SELECTION BY FEMALE DALL'S SHEEP, YUKON-TANANA UPLANDS, ALASKA

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## THESIS

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#### ABSTRACT

My objective was to assess the potential effects of military overflights on home range size, movement rates, habitat use, and habitat selection of female Dall's sheep (Ovis dalli) during 2-week sequential periods, April-July, 1999-2002. I examined sheep in 2 study areas overlain with designated military training airspace within the Yukon-Tanana uplands, Alaska. I examined the effects of study area, year, and sequential time period on: 1) mean home range size, 2) mean minimum hourly distance traveled by sheep, and 3) mean use and selection ratios for the habitat variables of elevation, slope, terrain ruggedness, aspect, and landcover class. Mean number of daily military sorties within sequential periods was used as a covariate in all analyses. I assessed habitat selection at 3 successive spatial scales defined as: 1) the regional geographical range of female Dall's sheep in the Yukon-Tanana uplands, 2) study areas (defined as the distribution of sheep within a localized area), and 3) selection within individual 2-week home ranges. Sheep home range size, movement rates, habitat use and selection ratios at the scale of region and study area differed between study areas, among years within study areas, and among sequential time periods within years within study areas, but did not vary in relation to military overflight intensity. I detected an effect of sorties on selection ratios at the home range scale; however, sorties explained <4% of the residual variation in these variables. I conclude that increases in intensity of military training operations during Major Flying Exercises (MFE's) over the Yukon-Tanana uplands were a relatively insignificant source of variance in activity and habitat use compared to the effects of seasons, years, and study areas.

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## **INTRODUCTION**

Anthropogenic disturbance has been defined in the context of wildlife conservation as a deviation in an animal's behavior from patterns occurring in the absence of human influences (Frid and Dill 2002). Disturbance by humans can be classified as direct or indirect, with direct impacts defined by habitat alteration through development (e.g., oil field development, mining, timber harvest, urban sprawl), while indirect impacts are defined by mechanisms that do not directly alter the habitat (e.g., military overflights, outdoor recreationists). Researchers have suggested that animal responses to human disturbance are analogous to anti-predator strategies (e.g., change in habitat use, fleeing, avoidance) (Berger et al. 1983, Gill et al. 2001, Frid and Dill 2002). Indirect disturbance may affect an animal's fitness if it interrupted energy assimilating activities, increased energy costs as a result of fleeing from or avoiding stimuli, or caused sub-optimal habitat use (Frid and Dill 2002).

In interior Alaska, concerns have been raised that military overflights may cause disturbance to Dall's sheep (Dept. of the Air Force 1997). To address this issue, Lawler et al. (2004) examined Dall's sheep foraging efficiency (time spent feeding relative to time spent scanning), activity budgets (proportion of time animals were engaged in bedding, standing, feeding, walking, and running behaviors), daily distance moved, home range size, and habitat use in relation to military overflights in the Yukon-Tanana uplands, Alaska, 1999-2002. Military overflights observed during 4 approximate 2-week field sessions, conducted in both 2000 and 2001, varied from a low of 2 to a high of 109 per session, with most (84%) of the overflights categorized as far (> 1500 m away). The

behavior of female Dall's sheep were significantly affected by group size, presence of lambs, distance to rocky terrain, study area, year, and date sequence (Lawler et al. 2004). Military overflights did not significantly affect activity budgets, foraging efficiency, daily distance moved, home range size, or habitat use of female Dall's sheep (Lawler et al. 2004).

Research investigating effects of military overflights on bighorn sheep (*Ovis canadensis*) suggested that responses to military jet aircraft noise were minimal (Weisenberger et al. 1996, Krausman et al. 1998). F-16 aircraft flown with a 90% power setting 125 m above-ground-level (AGL) over a 320-ha sheep enclosure produced sound pressure levels (decibels) of 85 – 110 dB, but did not alter behavior of bighorn sheep (Krausman et al. 1998). Heart rate of enclosed sheep increased above preflight levels during 21 of 149 overflights, and returned to preflight levels within 60 seconds  $\geq$  71% of the time, and within 120 seconds  $\geq$  92% of the time. Heart rates of captive bighorn sheep exposed to simulated overflight noise from military jet aircraft increased following the noise exposure for  $\geq$  3 minutes in the summer; however, they returned to resting rates in  $\leq$  1 minute in the spring (Weisenberger et al. 1996). Sheep demonstrated habituation to disturbance stimuli with increased number of exposures to simulated aircraft noise (Weisenberger et al. 1996).

Other studies reported negative responses of mountain sheep to non-military overflight activity. Female bighorn sheep moved significantly farther the day of helicopter surveys than on non-survey days in spring, summer and autumn and consistently abandoned sampling blocks during helicopter surveys (Bleich et al. 1994). In another study Dall's sheep reacted to 43 of 56 helicopter overflights (77%) by fleeing distances of 15 m - 1.5 km and reacted to helicopters at distances from 100 m to 3 km (Frid 1999). Low-flying aircraft, including helicopters, elicited a heart-rate response in bighorn ewes at distances less than 400 m (MacArthur et al. 1982). Foraging efficiency of bighorn sheep was 42.7% during the winter in areas with sightseeing helicopter activity compared to 74.6% in areas with no helicopter activity (Stockwell et al. 1991). Bighorn sheep responses to light aircraft (Cessna 172 and 182) varied with the altitude of the aircraft, although overflights < 50 m above ground caused sheep to leave an area (Krausman and Hervert 1983).

Investigations of the effects of military and non-military overflights on ungulates other than mountain sheep have shown mixed results similar to those obtained for mountain sheep. Habitat use of mule deer (*Odocoileus hemionus*), was consistent before, during and after overflights of low-flying, fixed-wing, aircraft (Cessna 172, 182 or Maule (M-5-235C)) (Krausman et al. 1986). Behavior (i.e., time spent bedding, standing, foraging, and traveling) of pronghorn (*Antilocarpa americana*), was not affected by military activity (i.e., overflight noise, noise from ordnance delivery, ground-based human activity) (Krausman et al. 2004).

Military fighter jets flying at low altitudes (i.e., flights to within 30 m AGL) had negative effects (e.g., increased daily movement rates) on caribou (*Rangifer tarandus*) in a few studies (Harrington and Veitch 1991, 1992, Maier et al. 1998). Caribou in the Red Wine Mountain herd reacted to direct overflights (30 m AGL and within 50 m of the animals) by running 22 of 27 times (Harrington and Veitch 1991). Median movement time after exposure to the overflight was 9 seconds (Harrington and Veitch 1991). Further, 70% of 260 caribou in the George River herd reacted to 13 overflights of 30-50 m AGL by running, with 35% of the individual animals running 10 seconds or longer (Harrington and Veitch 1991). Post-calving female caribou exposed to military jet overflights traveled significantly farther than control animals (Maier et al. 1998). Some researchers suggested overflights of military fighter jets during calving and post-calving had potential population-level effects through increased vulnerability of newborn calves to predation and starvation (Harrington and Veitch 1991, 1992; Maier et al. 1998). In contrast, there was no evidence that controlled military jet overflights caused the death of caribou calves or resulted in increased movements of cow-calf pairs over the 24 hour period following exposure to overflights (Lawler et al. 2005).

Research examining the effects of disturbance on animal performance has focused primarily on energetic costs (e.g., heart rates, feeding efficiency, movement rates). Theoretically, organisms selecting optimal habitats will successfully rear more offspring than animals selecting sub-optimal habitats (Levins 1968). Habitat selection (when resources are used disproportionately to their availability) is a complex process that varies spatially, temporally, and with the natural history of the animal. Identifying appropriate scales of analysis is therefore critical to studies of habitat selection (Orians and Wittenberger 1991, Johnson et al. 2002, Boyce et al. 2003). Assessment of habitat selection by female yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) demonstrated the selection of nest sites on the basis of vegetation density rather than food availability at a small scale, while selection criteria at a broader scale were positively

correlated to food availability (Orians and Wittenberger 1991). Had the studies of yellow-headed blackbirds been confined to a single arbitrary scale, the dynamics of their decision making processes would have been obscured (Orians and Wittenberger 1991).

The Final Alaska Major Operations Areas (MOA's) Environmental Impact Statement (EIS) Record of Decision (Dept. of the Air Force 1997) specified the need to evaluate the effects of military overflights on Dall's sheep populations. If female sheep responded to military jets I would expect either an increase in movement rates as sheep moved away from disturbance stimuli or decreased movement rates if female sheep selected and remained in habitats affording protection from disturbance stimuli (e.g., rugged terrain). I expected some variation in home range size, movement rates, habitat use, and habitat selection as result of changing availability of resources with snow cover, and seasonal migrations (Geist 1971, Whitten 1975, Seip and Bunnell 1985, Hansen 1996). If female sheep responded to military jets I would predict shifts in habitat use, habitat selection, home range size and movement rates as overflight intensity varied. For my thesis I defined these shifts to be potentially biologically significant if the variation in habitat use, habitat selection, movement rates, and home range size associated with military overflight intensity was detectable after accounting for the variation attributed to annual, seasonal, and study area differences. My objective was to assess the effects of increases in military overflight intensity during Major Flying Exercises (MFE's), compared to the background level of military overflights during Routine Flying Days (RFD's), on female Dall's sheep behavior.

My thesis extended the studies of Lawler et al. (2004) by examining potential effects of military overflight intensity on female Dall's sheep, home range size, movement rates, habitat use, and habitat selection. I assessed habitat selection across three spatial scales as described by Johnson (1980): 1) the regional geographical range of female Dall's sheep in the Yukon-Tanana uplands, 2) study areas (defined as the distribution of sheep within a localized area), and 3) selection within individual 2-week home ranges.

## **STUDY AREAS**

In 1976, the United States Air Force (USAF) established MOA's in Alaska designated for flight training. Since 1976, flight training has been characterized as RFD's or MFE's. USAF characterizes MFE's as an increase of  $\geq$  50% of the routine daily flying activity or an increase of 50 sorties (deployment of one military aircraft) per day (J. Hostman, United States Air Force, pers. comm.).

Two study areas within MOA 1 and MOA 2 in east central Alaska were selected based on similar environmental characteristics, minimal hunting and recreational pressure, and low densities of sheep. The names designated for the study areas were: 1) Cirque Lakes, located in the southwest portion of the Yukon-Charley Rivers National Preserve, and 2) West Point, which was approximately 35 km to the west of Cirque Lakes (Fig. 1). Military flights were restricted to >30 m AGL throughout most of the year in both study areas with 2 exceptions: 1) From May 10 through June 15 (lambing period) military overflights were restricted to a minimum >1525 m AGL in a 7 nautical mile



Fig.1. Cirque Lakes and West Point study areas and Military Operations Areas, Yukon – Tanana uplands, Alaska, 1999-2002.

radius centered at 64°48'00''N 143°45'00''W, and 2) from April 15 to August 31 military overflights were restricted within 2 nautical miles of either riverbank of the Charley River to >610 m AGL (11<sup>th</sup> Air Force Noise/Flight Sensitive Areas List 2002). Both of these exceptions impact the Cirque Lakes study area.

Both study areas were within the geographical region of the Yukon-Tanana uplands and were similar geologically and ecologically (Kelleyhouse and Heimer 1989). The Yukon-Tanana uplands were characterized as low, rounded mountains atypical of the more precipitous sheep habitats found within Alaska (e.g., Alaska Range, Brooks Range, Chugach Mountains, and Wrangell-St. Elias). Treeline in both study areas varied by aspect and ranged between 915 m and 1070 m. Vegetation in both study areas consisted of herbaceous plants, graminoids (*Carex* species and grass species) and dwarf shrubs (*Salix* species, *Vaccinium vitis-idea, Empetrum nigrum, Dryas octopetela, and Ledum palustris*). Spruce (*Picea spp.*) forests characterized lower elevations of both study areas. Twenty-five landcover types, derived from satellite earth cover classification maps, were common to both study areas (Ducks Unlimited, Inc. 1998; Appendix 1).

There were no historic climate data within the study areas. The closest weather stations were in Eagle, Alaska; approximately 100 km east of the Cirque Lakes study area, and Central, Alaska, approximately 45 km north of the West Point study area. Average monthly high and low temperatures for Eagle, Alaska ranged from a low of  $-36.4^{\circ}$  C (January, 1999) to a high of 22.4° C (June, 1999; National Weather Service; Appendix 2). Average monthly high and low temperatures for Central, Alaska ranged from a low of  $-37.3^{\circ}$  C (February, 1999), to a high of 23.2° C (June, 1999, 2000;

National Weather Service; Appendix 2). Average monthly precipitation for Eagle, Alaska ranged from a low of 0.0 cm (April, 2000), to a high of 12.0 cm (July, 2001; National Weather Service; Appendix 2). Average precipitation for Central, Alaska ranged from a low of 0.1 cm (May, 2000 and March, 2002), to a high of 10.0 cm (July, 2001; National Weather Service; Appendix 2).

#### **METHODS**

Each March, 1999-2002, up to 10 female sheep (2-10 years-old) were captured in each study area using a hand-held net gun fired from helicopters, and fitted with GPS\_2000L radio-collars equipped with two-axis activity sensors (LOTEK<sup>TM</sup> Engineering Inc., Newmarket, Ontario, Canada). Collars recorded coordinates every 4 hours (h) during 1999 and every 3 h during 2000-2002. Collars were retrieved and data downloaded by February of the following year.

For analysis, I used 9 sequential, approximately 2-week periods, beginning around April 1, and ending around August 10, for the 4 years of study (Table 1). I assumed the sequential time periods encompassed 3 distinct life history stages: 1) thirdtrimester of gestation (~ March 15 – May 15; Periods 1-3), 2) lambing (~ May 15 – June 15; periods 4-6), and 3) lactation (~ June 15 – Oct 15; periods 7-9) (Rachlow and Bowyer 1991). Variation in timing of period dates among years was a result of aligning periods to scheduled MFE's (Table 1). I obtained 14-128 locations per sheep for each period.

-	-					5			· ·	• 1		
		1999			2000			2001			2002	
Period	Start	End	# Days									
1	4/1	4/15	15	3/30	4/14	16	4/1	4/14	14	4/2	4/17	16
2	4/16	4/30	15	4/15	4/28	14	4/15	4/30	16	4/18	5/3	16
3	5/1	5/14	14	4/27	5/10	14	5/3	5/18	16	5/1	5/15	15
4	5/15	5/28	13	5/11	5/24	14	5/19	6/1	14	5/16	5/29	14
5	5/26	6/9	14	5/22	6/4	14	5/24	6/6	14	5/23	6/5	14
6	6/10	6/25	16	6/5	6/20	16	6/7	6/22	16	6/6	6/21	16
7	6/26	7/9	14	6/21	7/4	14	6/23	7/7	15	6/22	7/6	15
8	7/8	7/23	16	7/10	7/25	16	7/12	7/27	16	7/11	7/26	16
9	7/24	8/6	14		8/9	15		8/11	15		8/10	15
				7/26			7/28			7/27		

Table 1. Two-week periods used for analysis of habitat selection at the West Point and Cirque Lakes study areas, Yukon-Tanana uplands, Alaska 1999-2002. Bold italics indicate a Major Flying Exercises (MFE's) during that period.

Software in the LOTEK collar assigned an accuracy value to each coordinate based on the number of satellites communicating with the collar, and the quality of communication of the collar with the satellites. Coordinates derived under good conditions were assigned a value of three dimensions (3D), and coordinates derived under less ideal conditions were assigned a value of two dimensions (2D), and during poor conditions no coordinates were obtained. Prior to May 1, 2000, Selective Availability (a United States military process that degrades the accuracy of GPS units) was enabled, resulting in less precise locations.

To estimate the comparative accuracy of 2D and 3D locations before and after selective availability, I examined the assumed post-mortem data of collars retrieved from deceased sheep. Sheep were assumed deceased when GPS collars recorded 6 consecutive locations with activity values of 0. I compared the average distance of 2D-fixes and 3D-fixes from the arithmetic mean position of the collars calculated from the 3D-fixes of these stationary collars (n=14) before and after selective availability had been turned off. To assure that the collars of deceased sheep had not been moved by scavengers, I examined the activity data retrieved from the collars, and 2 individual collars with < 7 consecutive days of locations with activity values of 0 were omitted from the analysis. For my purposes of analyzing habitat selection, if average error estimates were less than 45m (GIS pixel size) location error was assumed to be inconsequential.

Collar failure, variable sampling intervals, death of sheep and variable satellite coverage resulted in variation in the number of locations obtained for each sheep. To estimate adequate sample size for home range calculations, I estimated the minimum number of locations necessary for minimum convex polygon (MCP (Mohr 1947)) size to become asymptotic. For a conservative estimate of necessary sample size, I examined the 2-week home range size of all sheep (n=17) alive throughout July 1999 (period 8, Table1). I assumed home ranges would be largest in the summer (Simmons 1982) thus requiring more locations for accurate home range calculations (Girard et al. 2002). Further, I assumed that collars deployed in 1999 would be less likely to have sufficient data for home range calculations based on the longer sampling interval (coordinates collected every 4 h in 1999).

I randomly subsampled the location dataset to generate 7 separate datasets composed of 10, 20, 30, 40, 50, 60, or 70 locations from the full 2-week data set for each sheep. I then calculated the MCP for each sample and compared the MCP for the sample (i.e., MCP<sub>sample</sub>) with the MCP from the entire dataset (i.e., MCP<sub>all\_data</sub>) in percentage form:

Percent MCP coverage = 100\*(MCP<sub>sample</sub>/MCP<sub>all\_data</sub>).

To determine the mean number of locations at which 95% of area in the MCP<sub>all\_data</sub> was covered, I fitted a generalized Von Bertalanffy growth curve (McLaren 1993) to the data (SAS Institute Inc. 1999) as follows:

$$y_{i} = S(1 - exp^{(-k(x_{i_{j}} - t_{0}))})$$

In that relationship the percentage of MCP coverage for sheep *i* in sample *j* is  $x_{ij}$ , the asymptotic percentage of MCP coverage is *S*, the rate at which the asymptotic percentage is approached is *k* (i.e., the growth rate), and the percentage covered with zero locations is  $t_0$ . Variables *S* and  $t_0$  were held constant. At infinite sample size, home ranges become

asymptotic at 100% coverage, so *S* was set to 1. Likewise, when no data were collected, zero percent of the home range is covered, so  $t_0$  was set to 0, therefore, only *k*, the growth rate, is estimated.

Behavioral data (MCP home range size and movement rates) were calculated for each sheep/year/period. Movement rates were estimated as the average straight-line distance between consecutive GPS locations divided by the elapsed time between locations.

To assess habitat selection I sampled used and available but unused habitat at 3 successively smaller spatial scales (Johnson 1980, Wiens 1989, Orians and Wittenberger 1991, Wiens et al. 1993). I defined: 1) Regional scale as the area encompassing home ranges of all sheep within a period, 2) Study Area scale as the area encompassing home ranges of all sheep within a period for both the Cirque Lakes and West Point areas separately, and 3) Home Range scale as the area encompassing used locations specific to individual sheep within a period (Fig. 2). Home range was estimated as a MCP for all radio-collared sheep relocations within a period. MCP's were estimated using animal movement extension to Arcview 3.2 (Hooge and Eichenlaub 1997).

To examine habitat selection, random unused points were generated (Arcview extension Random Point Generator 1.3, Jenness Enterprises) for each MCP for each scale of analysis. To assure random points generated for a unique scale and MCP were unused; all points within 45 m (GIS pixel size) of any used location for the same unique scale and MCP were omitted. I attempted to obtain a 1:1 ratio of unused to used locations for each sheep, within each period and scale of analysis (Manly et al. 2002).



Fig. 2. Example of spatial scales of analysis used to examine female Dall's sheep habitat selection, Yukon-Tanana uplands, Alaska 1999-2002. I defined Regional scale as the minimum convex polygon (MCP) for all used sheep locations within a unique year/period, Study Area scale as the MCP for all used sheep locations within a unique year/study area/period, and Home Range scale as the MCP for locations of each sheep within a unique year/study area/period.

Habitat attributes at the used and unused locations were derived from remotely sensed data using GIS (ARC/INFO, Environmental Systems Research Institute, Redlands, California, USA). Layers within my GIS included a 60 meter pixel Digital Elevation Model (DEM) (United States Geological Survey,

http://agdc.usgs.gov/data/usgs/geodata/dem/63K/), Landsat TM satellite earth cover classification maps (resolution 30 m) developed by Ducks Unlimited (Ducks Unlimited 1998), and an index of terrain ruggedness modified from Nicholson et al. (1997) described below.

The Ducks Unlimited (1998) classification of land cover types was based on the classification scheme of Viereck et al. (1992). To increase the power of statistical analyses, the original number of landcover classes (n=25) was broadly re-classified to four classes (forest, herbaceous/shrub, sparse vegetation/rock gravel, unknown/non-habitat) based on dominant overstory (Appendix 1). The unknown/non-habitat class was used to calculate proportional use of forest, herbaceous/shrub, sparse vegetation/rock gravel landcover classes, and then excluded from all other analyses. I re-sampled the Landsat maps (resolution 30 m) using nearest neighbor assignment and the DEM's (resolution 60 m) using bilinear interpolation to obtain a matching pixel size of 45m (Mather 1999).

To describe terrain ruggedness, I used the model of Nicholson et al. (1997). This model accounted for variation in slope and aspect within and surrounding each pixel. Specifically, the index was equal to the sum of the standard deviation of slope and the mean angular dispersion of aspect within a specified distance of the pixel center. For this model, I chose 450 m as the distance over which to calculate mean angular dispersion. When considering the hourly movements of all sheep in all years I found that only 4.4% of the 60,317 estimated movement rates, exceeded 450 m. Hence a radius of 450 m reflects the area a sheep typically encounters in 1 hour. I *summed* the standard deviation of slope and the mean angular dispersion of aspect rather than computing the terrain ruggedness index as the *product* of the standard deviation of slope and the mean angular dispersion of aspect as described by Nicholson et al. (1997). This avoided a 10-fold increase of the range of ruggedness estimates and preserved the proportional range of the original data in each component of ruggedness. Estimates of slope (%), elevation (meters), aspect class (N, S, E, W), landcover class, and terrain ruggedness at sites used by sheep, and at unused points, were derived from the GIS layers.

The number of sorties entering MOA 1 and MOA 2 per day was obtained from United States Air Force personnel (G. Rolf, United States Air Force, pers. comm.) and provided an estimate of overflight intensity in the general area. Simple linear regression (SAS Institute Inc. 1999) was used to examine the relationship between the number of sorties entering MOA 1 and MOA 2 each day. There was a positive linear relationship between the number of sorties entering MOA 1 and MOA 2 ( $r^2 = 0.92$ ; Fig. 3). Cirque Lakes was completely within MOA 1 while West Point was within MOA 1 and MOA 2 (Fig. 1). Because of the high correlation between sorties entering MOA 1 and MOA 2, and because both study areas were completely or partially within MOA 1, I used the number of daily sorties in MOA 1 as an estimate of overflight intensity for both the



Fig. 3. Relationship between numbers of sorties entering Military Operations Area (MOA) 1 and MOA 2, Yukon-Tanana uplands, Alaska, ~April 1 – August 10, 1999-2002.

Cirque Lakes and West Point study areas. I used Analysis of Variance (SAS Institute Inc. 1999) to estimate the influence of year, periods nested within years, and military flight training activity classification (RFD's, MFE's) on the number of sorties launched per day. For each sheep/year/period, I averaged the mean number of daily sorties entering the MOA's on the days the collar of each sheep recorded coordinates.

I performed a *post hoc* analysis estimating the proportion of sorties launched that were observed by Lawler et al. (2004) by year and study area. Combining data from both study areas, I estimated the number of military overflights observed per hour by Lawler et al. (2004) for each day of sheep observation. I used linear regression to examine the relationship between the hourly observation rate of military overflights and the number of sorties launched during the same days of observation by Lawler et al. (2004). I developed a crude estimate of the proportion of all sorties entering MOA 1 that would have been classed as low and close by Lawler et al. (2004) by assuming that the proportion of low and close aircraft observed by Lawler et al. (2004) was consistent among years, between study areas, and among periods. I estimated the number of low and close aircraft as a proportion of the total number of sorties launched by year and period in MOA 1.

## **Statistical Analyses**

I used bivariate plots to gain a visual understanding of how sorties related to home range size and the minimum distance traveled per hour. In addition to the effect of sorties, home range sizes and movement rates may vary as a function of study area, year, and period. To statistically estimate the effects of the number of sorties on home range sizes and the minimum distance traveled per hour, I used two approaches based upon Analysis of Covariance (ANCOVA). First, I included all variables, except for the number of sorties, in a nested design. Periods were nested within years and years were nested within study areas. The nested analysis assumes home range size and movement rates vary by study area, years within study area, and periods within years and study area. In effect, the nested analysis 'controls' for variation between study areas, years and periods and only allows the number of sorties to explain the residual variation after accounting for the nested effects. This is a conservative approach; the effect of sortie will only be observed after the other sources of variation have been accounted for. There is a possibility that some of the variability due to the number of sorties will be attributed to some of the nested effects if the number of sorties covaries with study area, year, or period. Hence, I also investigated a second approach, where study area, year, and period were crossed (factorial ANCOVA). For each unique sheep/period, I averaged the number of sorties entering MOA 1 for the days the GPS collar actually obtained coordinates, and used that average as a covariate in my analyses. Within the factorial design, I limited inferences to two-way interactions to aid interpretation.

I calculated the mean elevation, slope, and terrain ruggedness, proportion of aspect (north, south, east, west), and proportion of landcover class (forest, herbaceous/shrub, sparse vegetation/rock gravel; Appendix 1) of used and unused locations for each sheep within each period for each scale of analysis. For habitat use, a vector of average elevation, slope, and terrain ruggedness, proportional use of aspect, and proportional use of landcover class was calculated from used locations of each sheep within each period.

Experimental design for the assessment of habitat selection at the scale of region and study area incorporated design 3, while assessment of habitat selection at the scale of home range incorporated design 2 (Thomas and Taylor 1990). Habitat selection was estimated as a vector of selection ratios calculated from the means of used and unused points (e.g. mean use / mean unused) for all dependent variables for each sheep within the periods for each scale of analysis (regional, study area, home range; Neu et al. 1974, Alldredge and Ratti 1986, 1992, Thomas and Taylor 1990, Manly et al. 2002). For categorical variables (aspect and landcover class) selection ratios with a value > 1 represented selection for, while selection ratios < 1 represented avoidance of, the habitat attribute. For continuous variables (elevation, percent slope, and terrain ruggedness), selection ratios > 1 represented selection for higher than mean unused, while selection ratios < 1 represented selection of lower than mean unused.

To assess the effect of sorties on habitat use and selection, I used multivariate analysis of covariance (MANCOVA). For the MANCOVA, I nested period within year and year within study area (class variables). For each unique sheep/period, I averaged the number of sorties entering MOA 1 for the days the GPS collar actually obtained coordinates, and used that average as a covariate in my analyses to estimate if sorties influenced variation associated with the dependent variables. This is an appropriate design because there were 10 dependent variables (elevation, slope, terrain ruggedness, aspect (N, S, E, W), landcover class (forest, herbaceous/shrub, sparse vegetation/rock gravel) for both habitat use and habitat selection; use of a MANCOVA allowed assessing all variables at the same time and the nested design allows the test to focus on the effect of sorties. The nested design is appropriate for two reasons. First, I expected habitat use and selection to vary by period, year, and study area, independent of the number of sorties. Second, as mentioned above, this is a conservative approach. I argue that a conservative approach is more appropriate for this observational study in which controls (e.g. sheep populations never exposed to military overflights) were not available for comparison with the animals exposed to military overflights. All analyses were conducted using PROC GLM in SAS (SAS Institute Inc. 1999) and I used Type 3 SS to assess the influence of the class effects and sorties covariate. I examined the univariate output of the MANCOVA to assess the significance of the dependent variables. When the sorties covariate was found significant I performed linear regression (SAS Institute Inc. 1999) to assess the amount of variation on the dependent variable attributed to the covariate, Analyses were conducted with  $\alpha = 0.05$ .

I assessed the habitat variables for multicollinearity. While multicollinearity in MANCOVA does not affect the interpretation of class effects, it can affect the interpretation of individual independent variables by: 1) increasing confidence intervals on the regression coefficients to the point where they include 0, and 2) affect individual *P*-values to the point where they could change from significance to non-significance or vice versa (Grimm and Yarnold 1995). I assumed partial correlation coefficients greater than 0.8 might exceed a tolerance for multicollinearity that could potentially affect statistical models (Grimm and Yarnold 1995). If multicollinearity was detected in my

data sets, I conducted the analyses with one of the highly correlated variables eliminated and also with all variables included. Analyses were compared to determine if there were any differences in conclusions as a result of retaining or eliminating correlated dependent variables.

#### RESULTS

#### **Collar Data**

Prior to discontinuation of Selective Availability on May 1<sup>st</sup>, 2000, mean distance of 2D-fixes from the arithmetic mean of the stationary 3D-fixes ranged from 105.6 to 109.0 m, while mean distance of 3D-fixes from the arithmetic mean of the stationary 3Dfixes ranged from 46.4 to 85.1 m (Table 2). After selective availability was turned off, mean distance of 2D-fixes from the arithmetic mean of 3D-fixes ranged from 4.4 to 19.3 m, while mean distance of 3D-fixes from their arithmetic mean ranged from 2.9 to 6.0 m (Table 2). Imprecision of 2D and 3D relocation data was less than 45 m GIS pixel size after May 1, 2000. Relocation data prior to the discontinuation of selective availability introduced additional variation in my statistical models; however, I assumed that the variation would be minimal because: 1) original DEM pixels were resampled to a smaller pixel size, and bilinear interpolation assigns values based on the correlation of surrounding pixels, and 2) by broadly reclassifying the original Landsat TM satellite earth cover classification maps, I portrayed a more homogenous vegetative landscape and, 3) of the 4 GPS collars I used to assess the accuracy of 2D and 3D-fixes prior to the discontinuation of selective availability I found that on average 55.2 % of the 2D-fixes

				2D-fix	2D fiv	Total fixes	Average 2D	)	Average 3D		Average	
Sheep	Year	Beginning	End	(n)	(n)	(n)	distance	95% CI	distance	95% CI	distance	95% CI
169	1999	3-May	13-May	25	6	31	105.6	+/-27.3	70.8	+/-26.2	<b>98.8</b>	+/-23.0
173	1999	26-Oct	10-Nov	28	68	96	109.0	+/-63.0	46.4	+/-8.0	64.6	+/-19.9
179	2000	5-Apr	8-May	67	23	90	106.5	+/-16.5	68.0	+/-11.3	<b>96.7</b>	+/-13.1
175	2000	20-Mar	9-Apr	83	23	106	106.6	+/-16.1	85.1	+/-35.3	102.0	+/-14.7
176	2000	7-May	13-Jul	223	288	511	4.4	+/-0.9	2.9	+/-0.2	6.2	+/-0.4
172	2000	22-Jun	22-Sep	441	88	529	10.0	+/-0.8	5.6	+/-0.8	9.2	+/-0.7
162	2000	27-May	22-Sep	48	15	63	7.5	+/-1.8	5.0	+/-2.2	6.9	+/-0.17
173	2000	30-Oct	26-Nov	136	68	204	10.7	+/-1.8	5.8	+/-1.1	9.1	+/-1.3
166	2001	29-Mar	28-Jun	400	76	476	10.5	+/-0.9	5.6	+/-0.8	9.8	+/-0.8
169	2001	2-Dec	22-Dec	120	13	133	19.3	+/-4.8	6.0	+/-3.4	18.0	+/-4.4
161	2001	15-Dec	22-Dec	26	22	48	6.9	+/-2.0	3.8	+/-1.0	5.45	+/-1.2
173	2001	1-Dec	22-Dec	97	71	168	11.0	+/-2.4	5.2	+/-0.9	8.6	+/-1.5

Table 2. Mean distance (m) of 2D-fixes and 3D-fixes from the arithmetic mean calculated from the 3D-fixes of stationary GPS collars. Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002. Estimates prior to the discontinuation of selective availability (May, 1 2000) are indicated by bold font.

and 75.3% of the 3D-fixes were within one pixel (90 m) of the true Pixel in which the location occurred.

Within the von Bertalanffy growth model, the growth rate, *k*, was 0.059 (95% CI = 0.054 - 0.065; Fig. 4). This model predicted that with 45, 50, and 55 locations, the mean coverage in home ranges would be 93.0, 94.8, and 96 percent, respectively. The 95% confidence limit for the mean percentage covered at 50 samples was 93.3% to 96.0%. Sheep with < 50 locations for individual combinations of year/period were omitted from all analyses.

I wanted ~ 1:1 ratio of unused to used locations for each sheep, within each period of analysis, at the study area and regional scales. I obtained a cumulative total of 60,912 used locations for analysis of habitat use and selection across all scales of analysis. I developed a cumulative total of 60,780 unused locations for both the regional and study area scale, and 132,624 unused locations at the scale of home range. Small home range sizes resulted in difficulty generating random points greater than 45 m from used locations for 10 sheep/period combinations. Any sheep/period with < 20 randomly unused locations was omitted from the analysis (n=10).

## Sorties

There were significantly more (P < 0.001) sorties entering MOA 1 per day during MFE's (X = 45.4, SE = 3.97, n = 128 days) than during RFD's (X = 14.6, SE = 0.79, n = 407 days; Table 3). Mean number of daily sorties entering MOA 1 differed significantly among years (P < 0.026), and among periods within years (P < 0.001) (Table 3).



Fig. 4. Relationship between number of GPS locations and percent of maximum home range size of 17 female Dall's sheep, June 26 – July 9, in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999. A generalized Von Bertalanffy growth curve with 95% confidence intervals and an intercept forced at 0 was fit to the data. On average, sheep obtained 94.8 % +/- 2.1 of their maximum home range size with 50 locations. Maximum number of observed locations ranged from 58 – 85 with 16 sheep having > 75 locations.
Table 3. Mean number of daily sorties entering Military Operations Area 1 (MOA), Yukon-Tanana uplands, Alaska, 1999-2002. Significant differences existed between years (P < 0.026), and between periods within years (P < 0.001). Major Flying Exercises (MFE's) are indicated with bold italics. Periods 1-9 were sequential, approximately 2week periods, beginning around April 1, and ending around August 10. Variation in period dates among years was a result of assigning periods to scheduled MFE's.

	1999			2000			2001			2002		
Period	Mean		95% CI	Mean		95% C	I Mean		95% C	I Mean		95% CI
1	23.4	+/-	11.0	19.1	+/-	9.1	11.0	+/-	6.2	13.5	+/-	7.7
2	18.3	+/-	8.0	23.6	+/-	13.5	14.3	+/-	5.9	29.6	+/-	13.9
3	17.9	+/-	7.9	9.4	+/-	4.9	44.4	+/-	18.8	15.5	+/-	11.3
4	11.6	+/-	6.1	7.9	+/-	4.4	21.0	+/-	12.0	10.4	+/-	7.9
5	13.5	+/-	7.5	4.6	+/-	3.3	12.5	+/-	7.1	7.7	+/-	5.7
6	24.1	+/-	10.4	12.7	+/-	6.6	22.6	+/-	9.8	55.2	+/-	22.5
7	18.3	+/-	11.9	11.6	+/-	7.9	13.2	+/-	7.4	6.8	+/-	4.4
8	59.0	+/-	25.6	15.4	+/-	6.1	37.4	+/-	21.0	94.4	+/-	35.5
9	13.5	+/-	7.3	13.3	+/-	6.2	30.3	+/-	20.2	14.8	+/-	9.0

The USAF documented sorties entering MOA 1 on 44 days that field crews were observing sheep and observed military overflight activity in the Cirque Lakes and West Point study areas (Lawler et al. 2004). The proportion of sorties that were observed by Lawler et al. (2004) in MOA 1 ranged from a high of 28.0% at West Point during May 9 -18, 2000, to a low of 1.2% at Cirque Lakes during February 21 – March 5, 2000 (Table 4). The rate of sorties observed ranged from 0.12 - 8.00 per hour, while the number of sorties entering MOA 1 ranged from 1 - 50 per day (Lawler et al. 2004). Linear regression revealed a weak positive relationship ( $r^2 = 0.25$ ) between the number of flights observed and the total number of sorties entering MOA 1 during the same time period.

During 600 hours of sheep observations, Lawler et al. (2004) observed 376 military aircraft of which 28 (7.4%) were categorized as low (below 1524 m) and close (<1.6 km away). I estimated that the number of sorties that would have been low within MOA 1 ranged from a low of 4.8 during June 5-20, 2000, to a high of 112.5 during July 11-26, 2002 (Fig. 5).

## Behavior

A visual inspection of the bivariate plots revealed little evidence of an increasing trend between sorties, home range size and movement rates (Fig. 6-8). Further, the trend did not exhibit a monotonic increase with the number of sorties and means were highly variable. The nested ANCOVA analytical approach revealed home range size differed between study areas (P < 0.001), and among periods within years within study areas (P < 0.001). Based upon univariate  $R^2$  statistics, study area and period accounted for 62% of the variation in home range size. Home range size was larger, (P < 0.001) for sheep in

Year	<b>Field Dates</b>	Sorties	# observed CL	% observed CL	# observed WP	% observed WP
2000	Feb. 21 -Mar. 5	460	6	1.3	12	2.6
	April 10-21	276	22	8.0	12	4.3
	May 9 - 18	82	5	6.1	23	28.0
	July 15 -21	97	2	2.1	10	10.3
2001	March 13-24	295	27	9.2	50	16.9
	May 6-16	521	109	20.9	23	4.4
	June 7-21	349	22	6.3	34	9.7
	July 22 - Aug. 2	356	9	2.5	7	2.0

Table 4. Comparison of the total number of sorties entering MOA 1 with the number of military overflights observed by Lawler et al. (2004), at the Cirque Lakes (CL) and West Point (WP) study areas within the Yukon-Tanana uplands, Alaska, 2000-2001.



Fig 5. Estimated number of low (below 1524 m) and close (<1.6 km away) sorties entering Yukon MOA 1, Yukon-Tanana uplands, during approximate 2-week periods, early-April through early-August, 1999-2002.



Fig. 6. Bivariate plots depicting the relationship between sorties entering MOA 1 and female Dall's sheep home range size (top panel) and the minimum distance traveled per hour (lower panel) in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 7. Average home range size and movement rates in relation to the number of sorties entering MOA 1 for female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 8. Average home range size and movement rates in relation to the number of sorties entering MOA 1 for female Dall's sheep, by 2 week sequential time periods, Yukon-Tanana uplands, Alaska, 1999-2002.

West Point ( $X = 44.3 \text{ km}^2$ , SE = 3.2) than Cirque Lakes ( $X = 13.1 \text{ km}^2$ , SE = 3.9; (Fig. 9)). The sorties covariate provided no additional explanatory power of home range size, after accounting for the effects of study areas, and periods within years within study areas (P = 0.319).

The nested ANCOVA analytical approach revealed movement rates differed between study areas (P < 0.001), and among periods within years within study areas (P < 0.001). Study area and period accounted for 64% of the variation in home in movement rates. Mean minimum distance traveled per hour was longer (P < 0.001) for sheep in West Point (X = 122.6 m, SE = 3.8) than Cirque Lakes (X = 102.4 m, SE = 3.9, (Fig. 10)). The sorties covariate provided no additional explanatory power of movement rates, after accounting for the effects of study areas, and periods within years within study areas (P = 0.660).

The factorial ANCOVA yielded similar results to the nested design; home range size differed between study areas and the interaction of study area and period was supported. For home range size, neither sorties (P>0.997) nor any of the two-way interactions between sorties and study area (P=0.076), year (P=0.298), or period (P=0.535) were a significant source of variation. Movement rates differed between study areas and the data supported study area by year, study area by period, and year by period interactions. Neither sorties (P=0.851) nor any two-way interactions between sorties and study area (P=0.206) were a significant source of variation in movement rates.



Fig. 9. Mean home range size of female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 10. Mean minimum distance moved per hour by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.

#### Habitat Use at the Scale of Home Range

Pearson's correlation coefficients indicated multicollinearity between elevation and forest landcover (r = 0.87). I omitted elevation from my habitat use data, and performed MANCOVA on my reduced data sets. Excluding elevation from my analyses did not change the overall significance or coefficients from those results obtained from the complete data set. Results from models with elevation included are reported below.

Use of landcover class (Fig. 11-13), aspect (Fig. 14-17), terrain ruggedness (Fig. 18), slope (Fig. 19), and elevation (Fig. 20) differed between study areas (Wilks' Lambda,  $F_{9,514} = 151.83$ , P < 0.001), among years within each study area (Wilks' Lambda,  $F_{54,2626}$ = 8.82, P < 0.001), and among periods within years within study areas (Wilks' Lambda,  $F_{576, 4609} = 3.01, P < 0.001$ ). Study area, year, and period accounted for 29.7 – 61.2 % of the variation in habitat use and best explained variation in use of herbaceous/shrub landcover (61.2%; Fig. 12) proportional use of north aspect (56.5%; Fig. 14), and use of rugged terrain (42.5%; Fig. 18). Mean proportional use of herbaceous/shrub landcover was significantly higher (P < 0.001) in West Point (X = 33.4 %, SE = 1.0) than Cirque Lakes (X = 12.6 %, SE = 0.8, Fig. 12). In both study areas mean proportional use of north aspect accounted for less than 25% of the aspect usage; however, use of north aspect was greater (P < 0.001) at West Point (X = 10.5 %, SE = 0.5) than Cirque Lakes (X = 7.2 %, SE = 0.5, Fig. 14). In both study areas there was increased proportional use of north (Fig. 14) and east aspects (Fig. 17), and decreased proportional use of south aspects (Fig. 15) as summer progressed. Sheep at Cirque Lakes used steeper slopes ( $\overline{X}$  =



Fig. 11. Mean proportional use of forest landcover by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 12. Mean proportional use of herbaceous/shrub landcover by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 13. Mean proportional use of sparse landcover by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 14. Mean proportional use of north aspect by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 15. Mean proportional use of south aspect by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 16. Mean proportional use of west aspect by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 17. Mean proportional use of east aspect by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.





2000

early June Time Period

2001

early July

2002

early August

West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.

early May

**1**999

early April



Fig. 19. Mean percent slope used by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 20. Mean elevation used by female Dall's sheep in the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1999-2002.

54.5 %, SE = 0.3, P < 0.001) and more rugged terrain ( $\overline{X} = 75.5$  %, SE = 1.0, P < 0.001) than sheep at West Point ( $\overline{X} = 48.0$  %, SE = 0.3, Fig. 19;  $\overline{X} = 70.5$  %, SE = 0.7, Fig. 18). Conversely, sheep at West Point used higher elevations ( $\overline{X} = 1,336$  m, SE = 6.5, P < 0.001) than sheep at Cirque Lakes ( $\overline{X} = 1,175$  m, SE = 23.8, Fig. 20). The sorties covariate provided no additional explanatory power of habitat use after the variation of the class effects was accounted for (*Wilks' Lambda*,  $F_{9,514} = 1.24$ , P = 0.270).

#### Habitat Selection at the Scale of Home Range

Sheep selection of landcover class (Fig. 21-23), aspect (Fig. 24-27), terrain ruggedness (Fig. 28), slope (Fig. 29), and elevation (Fig. 30) at the scale of home range differed between study areas (*Wilks' Lambda*,  $F_{10,503} = 26.79$ , P < 0.001), among years within study areas (*Wilks' Lambda*,  $F_{60, 2640} = 4.96$ , P < 0.001), and among periods within years within study areas (*Wilks' Lambda*,  $F_{640, 5005} = 2.38$ , P < 0.001). The number of sorties was associated with sheep selection of habitat at the scale of home range (Wilks' Lambda,  $F_{10,503} = 5.73$ , P<0.001). Sorties decreased selection of herbaceous/shrub landcover (Fig. 22; P = 0.015), while increasing selection of sparse vegetation landcover (Fig. 23; P < 0.001), east aspect (Fig. 27; P = 0.088), south aspect (Fig. 25; P = 0.006), and steeper slopes (Fig. 29; P = 0.011). The sorties covariate only accounted for 1.1% of the variation in selection of herbaceous/shrub landcover, 3.5% of the variation in selection of sparse vegetation landcover, 0.2% of the variation in selection of east aspect, <0.01% of the variation in selection of south aspect, and <0.01% of the variation in selection slope selection ratios. Study area, year, period, and sorties accounted for 17.9 – 41.3% of the variation in habitat selection at the scale of home range, and best explained



Fig. 21. Selection ratios for forest landcover by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 22. Selection ratios for herbaceous/shrub landcover by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 23. Selection ratios for sparse vegetation landcover by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 24. Selection ratios for north aspect by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 25. Selection ratios for south aspect by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 26. Selection ratios for west aspect by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 27. Selection ratios for east aspect by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska, 1999-2002.



Fig. 28. Selection ratios for terrain ruggedness index by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, Alaska 1999-2002. Selection ratios > 1 represented selection for higher than mean unused, while selection ratios < 1 represented selection of lower than mean unused.



Fig. 29. Selection ratios for percent slope by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, 1999-2002. Selection ratios > 1 represented selection for higher than mean unused, while selection ratios < 1 represented selection of lower than mean unused.



Fig. 30. Selection ratios for elevation by female Dall's sheep in the Cirque Lakes (CL) and West Point (WP) study areas, Yukon-Tanana uplands, 1999-2002. Selection ratios > 1 represented selection for higher than mean unused, while selection ratios < 1 represented selection of lower than mean unused.

variation in selection of herbaceous/shrub landcover (41.3%; Fig. 22), north aspect (41.2%; Fig. 24), and rugged terrain (38.1%; Fig. 28). Relative to what was available in their study area, sheep at West Point were more selective for rugged terrain (X = 1.18, SE = 0.01) than were those at Cirque Lakes (X = 1.07, SE = 0.02; Fig. 28), while sheep at Cirque Lakes selected steeper slopes (X = 1.89, SE = 0.10) than those at West Point (X = 1.18, SE = 0.01; Fig. 29). Sheep in both study areas selected sparse vegetation/rock gravel land cover (X = 1.25, SE = 0.04; X = 2.19, SE = 0.22; Fig. 23), and southern aspects (X = 1.82, SE = 0.10; X = 2.61, SE = 0.31; Fig. 25).

### Habitat Selection at the Scale of Study Area

Sheep selection of landcover class (Fig. 21-23), aspect (Fig. 24-27), terrain ruggedness (Fig. 28), slope (Fig. 29), and elevation (Fig. 30), and at the scale of study area differed between study areas (*Wilks' Lambda*,  $F_{10, 513} = 150.84$ , P < 0.0001), among years within study areas (*Wilks' Lambda*,  $F_{60, 2692} = 12.76$ , P < 0.0001), and among periods within years within study areas (*Wilks' Lambda*,  $F_{640, 5104} = 3.32$ , P < 0.0001). Study area, year, and period accounted for 15.7 - 68.6% of the variation in habitat selection at the scale of study area, and best explained variation in selection of percent slope (68.6%; Fig. 29), rugged terrain (58.2%; Fig. 28), and south aspect (56.8%; Fig.25). Relative to what was available in their study area, sheep at Cirque Lakes selected steeper slopes (X = 1.88, SE = 0.04) than sheep at West Point (X = 1.29, SE = 0.01; Fig. 29). Sheep in both study areas selected rugged terrain (X = 1.22, SE = 0.01; X = 1.46, SE = 0.02; Fig. 28) and sparse vegetation/rock gravel land cover (X = 1.60, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 1.74, SE = 0.06; Fig. 23). Sheep at Cirque Lakes selected south aspects (X = 2.66, SE = 0.04; X = 0.06; Fig. 23).

0.1) more than sheep at West Point (X = 1.46, SE = 0.04; Fig. 25). The sorties covariate did not add additional explanatory power to the assessment of habitat selection at the scale of study area after accounting for the effects of study area, year within study area, and period within year within study area (*Wilks' Lambda*,  $F_{10,513} = 1.22$ , P = 0.273).

# Habitat Selection at the Regional Scale

Sheep selection of landcover class (Fig. 21-23), aspect (Fig. 24-27), terrain ruggedness (Fig. 28), elevation (Fig. 30), and slope (Fig. 29) at the regional scale differed between study areas (*Wilks' Lambda*,  $F_{10,513} = 76.66$ , P < 0.0001), among years within study areas (*Wilks' Lambda*,  $F_{60, 2693} = 7.33$ , P < 0.0001), and among periods within years within study areas (*Wilks' Lambda*,  $F_{640,5104} = 2.69$ , P < 0.0001). Study area, year, and period accounted for 25.7 - 59.4% of the variation in habitat selection at the regional scale, and best explained variation in selection of herbaceous/shrub landcover (59.4%; Fig. 22), north aspect (55.0%; Fig. 24), and rugged terrain (44.7%; Fig. 28). Relative to what was available in their study area, sheep at West Point and Cirque Lakes selected sparse vegetation/rock gravel land cover (X = 4.04, SE = 0.12; X = 3.57, SE = 0.10; Fig. 23), southern aspects (X = 1.50, SE = 0.04; X = 1.80, SE = 0.06; Fig. 25), rugged terrain (X = 1.28, SE = 0.13; X = 1.37, SE = 0.02; Fig. 28) steep slopes (X = 1.73, SE = 0.01;X = 1.96, SE = 0.03; Fig. 29), and higher elevations (X = 1.28, SE = 0.01; X = 1.12, SE= 0.02; Fig. 30) relative to what was available in their study area. The sorties covariate did not add additional explanatory power to the assessment of habitat selection at the regional scale after accounting for the effects of study area, year within study area, and period within year within study area (*Wilks' Lambda*,  $F_{10,513} = 1.36$ , P = 0.197).

### DISCUSSION

The number of sorties entering MOA 1 provided a region-wide estimate of overflight intensity associated with ongoing military flight-training over the Yukon-Tanana uplands; however, I had no data pertaining to flight paths, elevation, speed, or duration. Sortie data revealed nearly a 3-fold increase in sorties during MFE's; however, Lawler et al. (2004) reported no significant difference between the number of overflights observed during RFD's and MFE's in the vicinity of sheep in both study areas during 2000 and 2001. If flight paths were random within the MOA structure, I would assume that an increase in the number of sorties launched would increase the probability of individual sheep being overflown, but I found a weak relationship between the number of sorties launched and the number of overflights observed by Lawler et al. (2004), suggesting that the sortie data were most applicable to larger scale analyses.

Eight MFE's occurred during the 4 years of study. My crude estimate of the number of low and close sorties entering MOA 1 indicated considerable annual and seasonal variation, with generally the highest number of low and close sorties occurring during late July (Fig. 5). This criterion of low (below 1524 m) and close (<1.6 km away) was broader than the criteria specified by other researchers examining the potential effects of military aircraft on ungulate behavior (Harrington and Veitch 1991 (directed overflights within 30 m AGL), 1992 (within 1 km); Maier et al. 1998 (directed overflights within 30 m AGL); Krausman et al. 1998 (125 m AGL); Lawler et al. 2005 (slant distances of 30 m to 610 m or greater), however, the design of this study was observational and focused on the potential effects of actual flight training activity. Given

the large size of MOA 1 (16,184 km<sup>2</sup>), the probability that any individual sheep was overflown at low altitude was relatively low; therefore, the overall overflight intensity for my study likely was low.

Lawler et al. (2004) examined potential effects of military overflights on female Dall's sheep behavior within the home range scale. Specifically, they examined Dall's sheep activity budgets, foraging efficiency, movement rates, home range size, and habitat use and concluded that factors other than military overflights (e.g., study area, year, period, group size, presence of lambs, and distance to rocky terrain) explained most variation in sheep behavior (Lawler et al. 2004). Consistent with Lawler et al. (2004), I did not detect an appreciable effect of the approximate 3-fold increase in sorties entering MOA 1 during MFE's on home range size, movement rates, habitat use, or habitat selection at the regional, study area, or home range scale for female sheep within the Cirque Lakes or West Point study areas compared to a baseline average intensity of 14.6 overflights per day during RFD's.

My models suggested an effect of sorties on selection ratios for landcover class and aspect at the home range scale, however, sorties explained <4% of the residual variation in these selection ratios and there was no statistically significant effect at larger scales. With the majority of variation in habitat selection at the scale of home range attributed to year, season, and study area (17.9-41.3%), it is unlikely the variation attributed to sorties I observed was causing biologically meaningful effects. For example, rocky mountain elk (*Cervus elaphus*) demonstrated a dramatic shift in diet in response to hunting pressure, decreasing their utilization of fescue meadows 87% to 34%
while shifting to habitat use of forest landcover and increasing their diet of browse in parallel (Morgantini and Hudson 1995). Small changes in Dall's sheep selection of aspect, and a 3.2 % increase in selection of sparse vegetation landcover when they were already highly selective for sparse vegetation landcover (Fig. 23) makes it difficult to conclude there would be a biologically meaningful effect. Furthermore, if female Dall's sheep responded to military overflights with an anti-predator strategy (Frid and Dill 2002), I would expect they would have selected more rugged terrain, steeper slopes and higher elevations with increasing sorties, and I did not detect these responses. I conclude that variables other than military overflights (study area, year, period) were much more important in explaining daily movement rates, home range size, habitat use and habitat selection by female Dall's sheep in the Yukon-Tanana uplands.

Population surveys conducted during 1997-2002 reported considerable variability in the numbers of sheep counted within and among 8 sampling units within the Yukon-Tanana uplands (Lawler et al. 2004; Appendix 3). However, region-wide, there was little annual variability in the Dall's sheep population within the Yukon-Tanana uplands (Lawler et al. 2004). Moreover, no significant differences were detected in age ratios, pregnancy rates, number of lambs per 100 ewes, number of yearlings per 100 ewes, and survival of ewes between the Cirque Lakes and West Point study areas (Lawler et al. 2004). Given the results presented by Lawler et al. (2004) and results presented here, and given the relative stability of sheep populations within the region, it is unlikely that military operations over the Yukon-Tanana uplands were causing substantial biological effect. While there is substantial evidence that helicopter activity has the potential to negatively affect mountain sheep (Stockwell et al. 1991, Bleich et al. 1994, Frid 1999), the lack of significant response of female Dall's sheep in the Yukon-Tanana uplands to military jet activity is consistent with that reported for other mountain sheep (Weisenberger et al. 1996, Krausman et al. 1998, Krausman and Hervert 1983). Increases in military training activities during MFE's over MOA 1 and MOA 2, during 1999-2002 were unlikely to have caused deleterious effects to Dall's sheep populations; however, a substantial change in the quantity of background or maximum level of overflights could potentially alter the conclusions drawn from my research.

During my study overflight activity in MOA 1 had a baseline level of approximately 15 sorties per day during RFD's with nearly a 3-fold increase in sorties during MFE's. The greatest overflight intensity during the course of my study occurred in late July 2002 (period 8; Table 3), with an average of 94.4 +/- 35.4 sorties entering MOA 1 per day. I may not have observed a level of overflight intensity necessary to elicit an effect such as a shift in habitat use/selection. In addition, I examined areas that had an extended history of military aviation activities (> 20 years), and visual and auditory stimuli from these aircraft have been a continual and persistent part of the environment since 1976 (Department of the United States Air Force, 1997). It is possible that sheep had habituated to military overflights because multiple generations of sheep had been exposed to military operations. Without any preexisting data on sheep behavior and habitat use/selection in these study areas prior to the implementation of military overflights it was impossible to determine if habituation had occurred.

Sample sizes of GPS-marked sheep for this research were limited. Girard et al. (2006) demonstrated number of marked animals was more important than sampling frequency in assessing habitat selection in moose (Alces alces). Necessary number of animals varied spatially and temporally; however, < 12 individually marked moose would not have permitted detection of habitat selection because inter-individual variability was high (Girard et al. 2006). Similarly, sheep in my study areas displayed high interindividual variability as well as seasonal variability in habitat use and selection. I assume that availability of resources for both moose and sheep change seasonally. Alldredge and Ratti (1986) reported that Type II error rates (failing to reject the null hypothesis when it is false) decreased with increased number of marked animals. Further, results from simulation studies by Leban et al. (2001) suggested that a minimum sample of 20 animals with at least 50 locations per animal was necessary to accurately estimate resource selection. I had  $\leq 10$  GPS marked sheep per unique study area/year/period and thus the possibility for a Type II error was potentially large. Although I failed to meet the recommendations of Leban et al. (2001), I was able to statistically detect the effects of sorties on habitat selection at the scale of home range, even when the effect size was small. For example, in the best approximating model of habitat selection at the scale of home range, the effect of sorties was statistically supported, but only explained 3.5% of the variation in selection of sparse vegetation landcover.

While Dall's sheep populations are limited by various factors (e.g., snow free areas or quality of pastures in winter) (Hoefs and Cowan 1979, Seip and Bunnell 1985, Hansen 1996), I failed to detect an effect of an increase in sorties associated with MFE's on Dall's sheep habitat use/selection under the present scenario of USAF pilot training over the Yukon-Tanana uplands. A by-product of this research is the quantification of female Dall's sheep habitat use/selection across multiple spatial scales, and establishing baseline habitat selection data for sheep in this area. This baseline data will be useful in future studies of Dall's sheep habitat selection examining the effects of resource development, climate change etc. Therefore, my results contribute to an understanding of Dall's sheep habitat ecology.

In the context of my thesis, I repeatedly measured home range size, movement rates, habitat use, and habitat selection multiple times each year (1999, 2000, 2001, and 2002) in both the Cirque Lakes and West Point study areas. Specifically, within each study area and each year, I sampled during 9 sequential 2-week periods. Therefore, periods were nested within years, which were nested within study areas. While the design was balanced (i.e. same number of periods within each year and study area), I assumed there were confounding factors. I assumed habitat use and selection by Dall's sheep varied due to changing plant phenology and snow cover, though I did not directly measure plant phenology or snow cover. I assumed differences between periods would reflect changes in plant phenology and snow melt off. Annual variability in temperature and precipitation likely caused variability in plant phenology. Furthermore, the effect of period was likely confounded with study areas; as different study areas may have inherently different patterns in plant phenology. In short, the utilization of a nested design acknowledged the likelihood that study area, year and period were confounded.

In northern latitudes mountain sheep are generally limited to foraging areas with snow depth less than 30 cm during the winter (Hoefs and Cowan 1979, Seip and Bunnell 1985, Hansen 1996), and patterns of diet selection can be affected by as little as 10 to 15 cm of snow (Hansen 1996). Because winter habitat is limited, winter home ranges are generally smaller than summer home ranges. The extent and juxtaposition of winter habitats largely determines seasonal movements of Dall's sheep. For example, in the western Brooks Range, sheep may occupy separate summer and winter ranges with activity centers from 8.9 to 19.3 km apart (Ayers 1986). In contrast, some sheep in the same general area occupy contiguous summer and winter ranges (Ayers 1986). In the Mackenzie Mountains of the Northwest Territories, Simmons (1982) found that summer and winter ranges overlapped, but summer ranges were 30-90% larger than winter ranges. I found home range size of female Dall's sheep within the West Point and Cirque Lakes study areas were small during early April ( $X = 3.81 \text{ KM}^2$ , SE = 0.58; X = 2.72, SE =0.02; Fig. 9) suggesting the sheep were restricted to winter range. In both study areas home ranges expanded as summer progressed with sheep at West Point utilizing much larger home ranges ( $X = 139.33 \text{ KM}^2$ , SE = 10.84) than sheep at Circue Lakes (X =25.78  $\text{KM}^2$ , SE = 6.27; Fig. 9). This pattern was also consistent for movement rates in both areas; that is movement rates increased as summer progressed, ostensibly to take advantage of high quality resources as they become available (Fig. 10).

Dall's sheep have a limited and potentially variable amount of time to acquire resources necessary for reproduction and over-winter survival (Rachlow and Bowyer 1998). To maximize protein intake during short summers, Dall's sheep select vegetation in early phenological stages when levels of crude protein and digestibility are high (Whitten 1975, Winters 1980, Ayres 1986, Hansen 1996). Dall's sheep in Denali National Park demonstrated a shift in use of southern aspects to northern aspects as summer progressed (Whitten 1975). Similarly, sheep in the eastern Alaskan Range demonstrated an altitudinal shift from lower elevations to higher elevations as summer progressed (Winters 1980). Therefore, in areas with greater topographic diversity (i.e. aspects, slopes, ruggedness, and elevations), Dall's sheep will have access to a greater number of microclimates, and the amount of high-quality forage is expected to be available over a longer period of time (Whitten 1975, Winters 1980).

Snow pack begins to melt first on south and west aspects. Vegetation development occurs rapidly post melt-off. In my study, sheep shifted use from south and west aspects to east and north aspects as summer progressed (Fig. 14-17). This shift was most pronounced in the West Point study area (Fig.14-17). Interestingly, the selection of aspect depended upon the scale of analysis. At West Point, there was no selection for aspect at the scale of home range; however, seasonal shifts in selection of southern and western aspects to eastern and northern aspects were detected at study area and regional scales (Fig.24-27). Sheep at West Point selected higher elevations at the regional and study area scale; however, at the home range scale there was little selection for higher elevations until early July and after (Fig. 30)

Dall's sheep are known to select rugged terrain. For example, in Denali National Park, Rachlow and Bowyer (1998) found that female sheep selected areas close to escape terrain (i.e., steep rugged areas). Furthermore, rugged terrain (indexed by subtracting straight-line distances from those measured by following contour lines) was selected by females during peak lambing. I detected consistent selection by female sheep for rugged terrain at the regional and study area scale for both the West Point and Cirque Lakes study areas (Fig. 28). However, sheep at Cirque Lakes were highly variable in selection of rugged terrain and no patterns could be ascertained at the home range scale (Fig. 28). Furthermore, sheep at West Point exhibited a distinct shift to no selection of rugged terrain approximately 1 month post lambing at the study area and home range scale (Fig. 28). I hypothesize that this delayed shift to rugged terrain may be driven in part by diversity of microclimates in rugged terrain, which would promote a mosaic of high quality forage during lactation.

## **Future Studies**

Wildlife researchers are often tasked with identifying the effects of disturbance events that are pre-existing. Inferences from such observational studies are often limited because they lack characteristics of experimental studies, such as pre-treatment data, comparable controls, and assigned treatments (Cook and Campbell 1979). For example, my study would have greater inference strength if it had been possible to collect base-line data before overflights commenced. I could have incorporated a quasi-control by including another similar study area in which there were no overflights. This study design is analogous to the 'untreated control group design with pretest and posttest data collection' of Cook and Campbell (1979; p. 103). Assigning treatments, in the form of overflights, would increase inference strength further. Treatments could include a variety of overflight elevations or sound levels. However, the implementation of such a study would be expensive, logistically difficult and resource managers may be reluctant to intentionally expose wildlife to overflight activity. The results might also be confounded by habituation.

The role of habituation in the study of overflights deserves special consideration because there had been overflights for over 20 years within my study areas. Habituation to overflights has consequences for both management and the interpretation of my results. In a management context, habituation may allow sheep to adapt to overflight disturbance and reduce any effects on levels of fitness. As such, habituation may be positive. However, habituation complicates the interpretation and application of my results; specifically, sheep elsewhere that have not been exposed to overflights may be much more sensitive to overflights than what I observed.

Because of these complications, the most appropriate study design from a management perspective is to collect pre- and post-treatment data on any population of sheep that might be affected in the future. Because sheep may habituate, such studies will have to be of long enough duration to document potential habituation. Monitoring will be important, especially if populations do not habituate and begin to decline.

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Appendix 1. Landcover types (n=25) derived from Landsat TM satellite earth cover classification maps characterized the Yukon-Tanana uplands, Alaska, 1999-2002 (Ducks Unlimited, Inc. 1998). The original Ducks Unlimited (1998) classifications of land cover types were based on the classification scheme of Viereck et al. (1992). To increase the power of statistical models, the original number of landcover classes was broadly reclassified to 4 classes (forest, herbaceous/shrub, sparse vegetation/rock gravel, unknown/non-habitat) based on dominant overstory.

<b>Original Landcover Classification</b>	Reclassification	Characteristic species					
Closed Needleleaf	forest	> 60% canopy, <i>Picea spp</i> .					
Open Needleleaf	forest	25-60% canopy, Picea spp.					
Open Needleleaf - Lichen	forest	25-60% canopy, Picea spp., lichen					
		10-25% canopy, Picea, Alnus, Betula,					
Woodland Needleleaf	forest	spp.					
Woodland Needleleaf - Lichen	forest	10-25% canopy, Picea, Alnus, Betula lichen spp.					
Closed Deciduous - Birch	forest	> 60% canopy, Alnus, Betula, and Populus spp.					
		25-60% canopy Alnus, Betula, and					
Open Deciduous	forest	Populus spp.					
Closed Mixed Needleleaf/Deciduous	forest	> 60% Alnus, Betula, and Picea spp.					
Open Mixed Needleleaf/Deciduous	forest	25-60% Alnus, Betula, and Picea spp.					
Tall Shrub	herbaceous/shrub	Alnus and Salix spp.					
Low Shrub	herbaceous/shrub	Betula and Salix spp.					
Low Shrub - Lichen	herbaceous/shrub	Betula and Salix lichen spp.					
Low Shrub - Tussock	herbaceous/shrub	Betula and Erioferum spp.					
Dwarf shrub	herbaceous/shrub	Dryas, Cassiope, Vaccinium spp.					
		Dryas, Cassiope, Vaccinium lichen					
Dwarf shrub - Lichen	herbaceous/shrub	spp.					
Dry Herbaceous	herbaceous/shrub	Carex spp.					
Tussock Tundra	herbaceous/shrub	Erioferum spp.					
		>50% barren, >20% vegetated. <i>Poa</i>					
Sparsely Vegetated	sparse vegetation/rock gravel	Carex spp.					
Rock/Gravel	sparse vegetation/rock gravel	NA					
Non-Vegetated Soil	sparse vegetation/rock gravel	NA					
Clouds	unknown/non-habitat	NA					
Cloud Shadows	unknown/non-habitat	NA					
Terrain Shadow	unknown/non-habitat	NA					
Clear Water	unknown/non-habitat	NA					
Snow	unknown/non-habitat	NA					

Weather Station	Average	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Central, AK	High Temperature (°C)	1999	-32.4	-23.4	-9.3	4.7	13.9	23.2	22.3	20.8	13.2	-4.5	-18.7	-23.1
		2000	-29.6	-10.2	-3.8	4.6	12.3	23.2	22.2	16.0	9.6	-3.0	-11.4	-19.8
		2001	-25.0	-11.7	-10.1	4.5	11.7	22.6	20.7	19.0	14.4	-4.3	-17.5	-21.7
		2002	-27.2	-16.9	-3.8	2.6	15.6	22.1	23.1	16.9	13.6	1.8	-8.2	-13.0
	Low Temperature (°C)	1999	-36.5	-37.3	-27.4	-12.8	-1.5	7.8	7.6	6.1	-1.7	-12.8	-28.8	-32.9
		2000	-35.1	-20.9	-19.0	-15.1	-1.5	8.0	7.4	2.7	-2.7	-14.0	-21.1	-28.4
		2001	-29.8	-24.9	-27.2	-11.9	-1.8	6.8	8.0	4.6	-2.8	-13.7	-25.9	-31.1
		2002	-32.0	-28.8	-26.6	-14.3	-1.5	5.9	8.9	4.2	-0.1	-8.6	-16.2	-21.9
	Precipitation (cm)	1999	0.8	0.6	1.2	0.4	1.5	4.0	4.1	8.6	2.7	3.7	2.1	3.5
		2000	1.4	1.2	0.5	0.2	0.1	4.2	5.6	5.5	2.6	2.1	0.7	1.4
		2001	1.3	1.1	1.3	1.4	0.9	4.3	10.0	3.6	1.0	1.7	0.4	0.8
		2002	1.8	0.4	0.1	1.2	0.5	3.9	4.7	6.2	3.9	4.9	1.1	1.4
Eagle, AK	High Temperature (°C)	1999	-30.7	-19.0	-5.2	5.9	13.0	22.4	21.6	20.6	12.7	-1.7	-12.9	-17.5
		2000	-29.2	-6.8	-1.5	4.4	11.8	21.9	20.5	16.2	9.4	-0.6	-7.3	-16.1
		2001	-22.2	-9.9	-6.4	5.4	12.5	21.9	20.6	19.3	14.1	-1.2	-12.5	-15.8
		2002	-23.7	-10.9	-4.9	2.8	16.0	22.3	21.6	16.6	13.8	4.6	-0.7	-6.5
	Low Temperature (°C)	1999	-36.4	-32.3	-22.4	-8.5	-1.2	8.3	8.1	6.3	-0.7	-10.0	-24.2	-29.2
		2000	-34.0	-16.4	-17.9	-12.6	-0.4	7.9	8.8	3.4	0.0	-10.7	-16.2	-25.0
		2001	-27.5	-20.0	-24.0	-8.5	-1.2	6.1	8.7	5.5	-1.8	-10.3	-20.6	-25.9
		2002	-28.7	-24.4	-24.0	-13.2	-0.7	6.0	8.3	5.0	0.4	-5.1	-7.3	-11.7
	Precipitation (cm.)	1999	0.7	1.4	0.4	2.4	2.7	0.4	5.6	5.3	4.3	2.7	2.7	3.0
		2000	1.0	0.3	0.8	0.0	2.8	5.8	9.8	5.0	4.4	2.5	0.7	2.2
		2001	2.3	1.4	1.6	0.5	3.8	2.4	12.0	0.9	1.8	3.7	1.1	0.8
		2002	1.8	0.3	0.4	1.4	2.1	5.5	3.7	8.0	2.9	4.2	1.7	2.2

Appendix 2. Mean monthly temperatures (°C), and precipitation (cm) (National Weather Service), Eagle and Central, Alaska, 1999-2002.

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	Year	Total Sheep Survey Time		Ewes	Lambs	Yearlings	Rams
Study Area		_	(h)			-	
West Point	1999	140	3.0	63	34	16	27
	2000	179	na	82	16	32	49
	2001	131	3.0	67	22	9	33
	2002	118	2.9	62	21	9	26
Cirque Lakes	1983	66	na	26	10	9	21
	1984	27	4.8	16	4	8	1
	1990	107	2.5	47	15	19	26
	1993	58	2.5	38	9	1	10
	1994	63	2.6	21	9	9	24
	1995	76	3.2	27	9	11	29
	1997	77	3.2	42	13	3	19
	1998	62	2.1	18	9	3	32
	1999	69	3.7	33	13	15	8
	2000	na	na	na	na	na	na
	2001	52	3.4	16	4	5	23
	2002	57	2.6	28	16	7	6

Appendix 3. Summary statistics for Dall's sheep aerial surveys within the Cirque Lakes and West Point study areas, Yukon-Tanana uplands, Alaska, 1983-2002 (na = not available).

*Source:* Lawler, J.P., B. Griffith, D. Johnson, and J. Burch. 2004. Effects of military jet overflights on Dall's sheep in interior Alaska. Report to the Department of the Air Force, 11<sup>th</sup> U.S. Air Force, Elmendorf Air Force Base, Alaska, Appendix A.