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The Effects of Military Jet Overflights on Dall's Sheep in Interior Alaska

Report

to the

Department of the Air Force

11th U.S. Air Force

Elmendorf Air Force Base, Alaska

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SUMMARY

Research efforts on wildlife species have documented a variety of responses to aircraft overflights. Responses may be short term or long term and may include changes in movement, activity, and behavior as well as changes in habitat selection and use. These changes may have negative impacts on wildlife populations. Research was initiated in March 1999 to investigate the impacts of military overflight activity on Dall's sheep (*Ovis dalli*) in interior Alaska and to assess the effectiveness of current mitigation measures intended to reduce impacts on Dall's sheep populations. We investigated the impacts of military jet aircraft on Dall's sheep using: 1) populations surveys; 2) productivity and survival rates in mitigated and non-mitigated areas; 3) behavior in relation to military overflight activity; and 4) daily movements, home range size, and habitat use in relation to military aircraft activity.

Two study sites were selected for intensive investigations of the effects of military overflight activity on Dall's sheep. One (Cirque Lake) is located in Yukon-Charley Rivers National Preserve and is overlain by airspace mitigated for Dall's sheep. Military aircraft flying over this area are restricted to flying 5,000 feet above ground level from May 10 - June 15 (lambing season). Because the floor of this military airspace is 100 feet above ground level at other times of the year, sheep in this area may be exposed to a significant change in flying activity during the 1 month mitigation period. The 2nd site (West Point) is located approximately 35 miles to the west of the 1st site and has no associated mitigation measure for Dall's sheep.

To investigate Dall's sheep daily movements, home range size, and habitat use in relation to military aircraft activity, Global Position System (GPS) radiocollars were placed on sheep. These collars record the time and location of the collared sheep. Ten sheep were captured at each site in March of 1999, 2000, and 2002 (20 radiocollared Dall's sheep per year). During March 2001, 10 sheep were radiocollared at West Point but due to problems locating sheep, only 7 were captured at Cirque Lake. Weights of sheep were taken during the radiocollaring capture operation and a blood sample was drawn for pregnancy determination and disease screening. A series of physical measurements were recorded for captured sheep. Dall's sheep mortalities were investigated as soon as was reasonable.

In addition to radiocollars, ground crews observed sheep before, during, and after Major Flying Exercises (Cope Thunders) and recorded sheep behavior. Sound levels of overflight activities were recorded and used during analysis. We analyzed Dall's sheep behavior in relation to: the number of military aircraft we observed per day; behavior before, during, and after an overflight event; and, behavior during an overflight event relative to the sound level and the proximity of the overflight event. Sheep behavior was analyzed as: the proportion of time Dall's sheep were active; the feeding efficiency of Dall's sheep; and the proportion of time sheep were engaged in bedding, standing, feeding, walking and running.

Aerial surveys for Dall's sheep were conducted with a helicopter in 8 study units within the interior Alaska, Military Operations Areas in June or July of 1997-2002. We found no differences in population trends between areas mitigated and not mitigated for low-level military aircraft. Although considerable fluctuation existed in sheep numbers in individual survey units, the overall sheep population in the Yukon-Tanana Uplands was relatively stable from 1997 to 2002 and there was little overall variability in the total count from year to year (coefficient of variation = 7%).

There were no statistical differences in the pregnancy rates, lamb to ewe ratios, or yearling to ewe ratios between Cirque Lake (mitigated) and West Point (non-mitigated). There was a statistical difference in the mean body weights of captured ewes at the 2 study sites with ewes at West Point heavier than those at Cirque Lake. In general, there was greater variation in pregnancy rates, lamb to ewe ratio, yearling to ewe ratio, and body weights among years than there was between study sites. Survival rates of adult ewes were similar between the 2 study sites.

Field crews observed Dall's sheep behavior, overflight activity and collected information on sound levels during 4 field sessions per year during 2000 and 2001. Military overflight activity was extremely variable among years, seasons, and between study areas. There was no difference in the number or frequency of overflights observed between the mitigated study site and the non-mitigated site. There was no difference in the number of observed overflight before and after Cope Thunder excercises in comparison to during Cope Thunder excercises. Loud and low overflight events were rare at both study sites. The number of overflights we observed over Dall's sheep on a given day did not influence Dall's sheep behavior. Significant differences occurred in the feeding efficiency of Dall's sheep when behavior was examined in the 10 minutes before, during and 10 minutes after an overflight event. In models that included all seasons, Dall's sheep ewe feeding efficiency was higher after the overflight event in comparison to before the overflight event. In models that just examined lambing season and early summer (May, June and July), sheep feeding efficiency was higher before the overflight event in comparison to during the event. In models that considered the proximity and sound level of overflight events, a higher proportion of sheep were active with increasing sound levels. In models that just examined lambing season and early summer, more sheep were active with closer military overflights. In all models, factors other than military overflights, explained greater proportions of the variation in sheep behavior. In particular, the date sequence (time of year of the field observation) nested within year and study site explained greater proportions of the variability that we observed in Dall's sheep behavior than did military overflight activity.

We observed no significant effect of the number of military aircraft sorties launched on 2-week within-home-range scale: 1) total distance moved; 2) home range size; or 3) habitat use (proportional use of landcover classes and aspect classes, average elevation, slope, terrain ruggedness, and relative vegetation biomass. However, there was substantial variance in total distance moved, home range size and habitat use between study areas, among years within study areas, and among 2-week sequential periods within years within study areas. Once this natural variance was accounted for, the number of military aircraft sorties added no further explanatory power to the assessment of variance in sheep behavior and habitat use.

We conclude that the levels of military activity which we observed in this study during Major Flying Exercises (~60 sorties/day) generally did not cause significant effects on sheep behavior and habitat use at the home range scale when compared to the background level of military sorties (~ 20 sorties/day). When statistical differences in feeding efficiency and activity of groups of sheep were observed, military aircraft activity typically accounted for a small proportion of the total variance in sheep behavior, the direction of these effects were variable for sheep, and there were no overt indications that military overflights affected sheep populations during 1999-2002. Few of the overflights that we observed were low or loud and the mitigation measures in place at the Cirque Lake study site provided no detectable reduction in sheep response to military overflights. We emphasize, however, that 1) the studied sheep population has had opportunity to acclimate to military overflights for over 20 years, 2) we made no comparisons to areas that were free of military overflights and thus cannot draw conclusions regarding the effect of the background level of military overflights on sheep behavior and populations, and 3) if the nature, intensity, or frequency of military flights in interior Alaska changes substantially compared to the situation described here, then sheep may respond differently than documented in this study.

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The Effects of Military Jet Overflights on Dall's Sheep in Interior Alaska

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INTRODUCTION

DALL'S SHEEP

Dall's sheep (*Ovis dalli dalli*) can be found only in Alaska, USA, and Yukon Territory, Northwest Territories and British Columbia in Canada. They are the northern most species of mountain sheep in North America. In contrast to bighorn sheep (*Ovis canadensis*), Dall's sheep and Stone's sheep (*Ovis dalli stonei*) are often termed thinhorn sheep. Of the sub-species of wild sheep in North America Dall's sheep are the most common (Valdez and Krausman 1999). This distinction however, does not make them a common animal. Valdez and Krausman (1999) estimated the wild population of Dall's sheep in 1991 to be 99,750 animals. The majority (73,250 animals) occur in Alaska (Fig. 1). Within Alaska, Dall's sheep inhabit some of the most inaccessible regions of the state. This inaccessibility also makes these regions attractive to United States Air Force (USAF) as areas for combat flight training (Fig 1).

Dall's sheep are highly loyal to their home ranges and young sheep acquire home ranges from adults (Geist 1971, Nichols and Bunnel 1999). Seasonal range use patterns of Dall's sheep differ between populations. In some instances, Dall's sheep populations appear to be relatively sedentary and summer ranges are merely expansions of winter ranges (Heimer 1973, Summerfield 1974, Simmons 1982, Ayres 1982, Durtsche et al. 1990, Burch and Lawler 2001). In other instances, Dall's sheep migrate to distinct seasonal ranges (Geist 1971, Hoefs and Cowan 1979, Ayers 1986). Migration routes may be extremely fragile and routes may be lost to succeeding generations if older animals who lead the migration are eliminated from the population (Geist 1971, Nichols and Bunnel 1999). This may explain why areas of apparently suitable habitat are unoccupied by Dall's sheep (Geist 1971). Dall's sheep are primarily found in alpine areas with steep rugged terrain for escaping predators with nearby grass/sedge meadows. In winter, Dall's sheep occupy areas characterized by light snowfall and strong winds that blow the area clear of snow and expose forage (Nichols and Bunnell 1999). Available forage becomes increasingly limiting with increasing levels of snow cover. Sheep habitat can therefore be characterized as patchy and disjunct with the degree of patchiness varying by area. Bleich et al. (1994) noted the potential for disturbance effects to be "exacerbated for animals living in heterogeneous environments, where critical resources are limited and widely distributed: mountain sheep are an excellent example of such a species". Dall's sheep therefore, have the potential to be negatively affected by disturbances such as low-level military jet overflights.

MILITARY OPERATIONS AREAS

Military Operations Areas (MOA) in Alaska were established in 1976 as Special Use Airspaces designated for nonhazardous military flight training activities such as air combat tactics, formation training, and aerobatics. Since 1976 the expectations of the military and, therefore, expectations of training goals have changed. Concurrent with these changes were changes in weapon and aircraft technology and changes in the numbers and types of aircraft being flown in Interior Alaska. In the late 1980s and early 1990s, the USAF initiated several actions that led to a significant increase in training activity in Alaska. These actions included increased numbers of Military Training

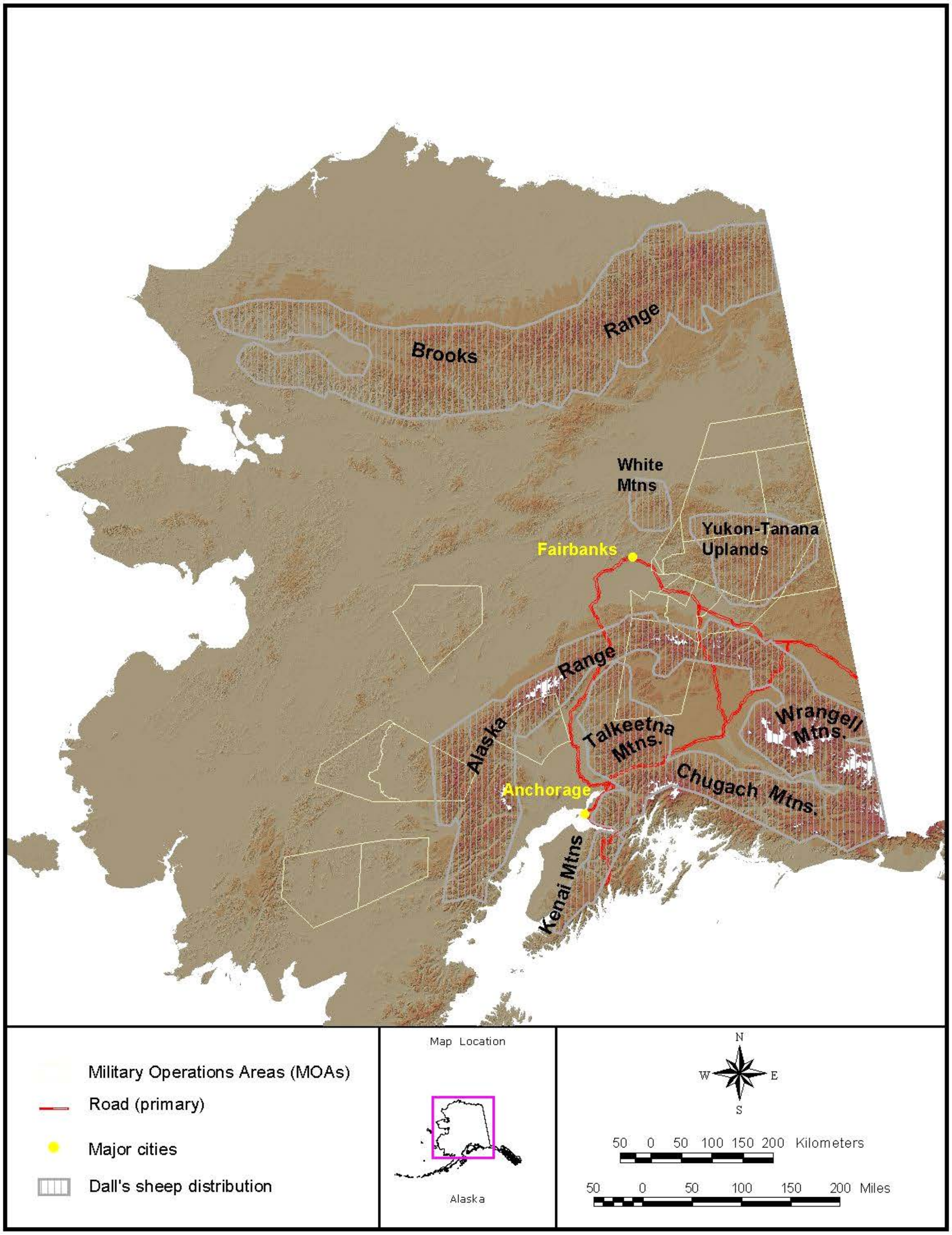


Figure 1. Dall's sheep distribution and military special use airspace (MOAs) in Alaska.

Routes, initiating Major Flying Exercises (MFEs), and increasing the size of Military Operations Areas (MOAs). Each of these actions required a separate Environmental Impact Assessment, and all but the MOA increase were concluded with a Finding of No Significant Impact. An Environmental Impact Statement was prepared for the proposed MOA increase, and a Record of Decision was signed in 1997 (Dept. of the Air Force 1997). Among the changes proposed to the existing arrangement and accepted in the ROD were different boundaries for some MOAs, additional MOAs, the addition of supersonic flight to some MOAs, standard floors for some of the supersonic operations in existing MOAs, and higher numbers of aircraft authorized to participate in Major Flying Exercises (MFE). The Final EIS and the ROD included a number of mitigation measures designed to minimize negative impacts on wildlife. The ROD also established committees made up of Air Force and resource agency representatives to monitor the effectiveness of the mitigation measures. Among other needs, these committees recognized the importance of determining the effectiveness of the mitigation measures on Dall's sheep and the need to evaluate the impacts of low-level military aircraft on Dall's sheep.

Military aircraft in all MOAs may be involved in routine flying exercises or more complex MFEs. The Final EIS (1995) and the ROD (1997) make a broad distinction between MFEs flying days and routine training days. Routine training days are typically limited to 240 days per year due to budget constraints. Routine training days include the routine joint and combined training as well as exercise training such as Low-Altitude Navigation and Targeting Infared for Night exercises, weapons training deployment, Air National Guard and Air Force Reserve deployments, and muti-national excercises. MFE training days can occur no more then 60 days per year and typically include aircraft that are participating in the MFE as well as aircraft that are participating in routine training, although routine training levels are typically reduced at this time. Characteristics that would change a routine flying exercise into an MFE would be a 50% or greater increase in the daily flying activity rate out of Eielson or Elmendorf AFBs or an increase of 50 aircraft operations per day. However, there is no single criteria that distinguishes an MFE from a routine training exercise (Jim Hostman, US Air Force, pers. com.). Instead, this designation is determined by a committee of exercise planners and air space managers. MFEs typically include between 55 and 110 aircraft and aircraft of different types. Participates typically come from numerous organizations, both national and international (Jim Hostman, US Air Force, pers. com.).

Training exercises typically occur between 0800h and 2200h, Monday through Friday and, on average, up to 2 weekends per 3-month period. MFEs occur Monday through Friday, 0800h through 1800h but are most concentrated between from 1000h through 1200h, and 1500h through 1700h. Training on weekends may also occur on average of 2 weekends per quarter. In general, 1 MFE is to take place between February and April, 4 MFEs between May and August, and 1 MFE between October and November. A typical MFE is 10 days in duration but can last as long as 15 days. Up to 100 aircraft a day can be involved in an MFE, with each aircraft flying up to 2 sorties (a single aircraft take-off, flight, and landing) per day for a total of 200 MFE sorties per day (Dept. of the Air Force 1995). No MFEs are to be conducted during September, December, or January, or during the week prior to or the week after the 4th of July. There is a minimum interval of 2 weeks between MFEs.

The largest MFEs that occur in Alaska are termed "Cope Thunders". There are normally 4 Cope Thunder exercises each year and they each last approximately 2 weeks. Air activity typically occurs during 2, 3h blocks per day and typically occurs Monday through Friday. The most intense flying occurs during air-to-air combat training and occurs during 2, 50-minute (sometimes longer) windows per day. MOA use is primarily in the Yukon 1, 2, 3A, and 4 MOAs (Fig. 2). Most of the flying below 5000 feet above ground level occurs in these same 2, 50-minute windows. An average sortie time below 5000 feet above ground level does not exceed 30 minutes.

Mitigation measures specifically targeted to Dall's sheep exist in 2 locations within the MOA structure and 1 location just outside the MOA structure (Fig. 2). In the Dall's sheep lambing area that falls primarily in the Fox MOA, military aircraft are restricted to flying 5000 feet above ground level from 1 May through 30 June and from 15 November through 15 December (11th Air Force Noise/Flight Sensitive Areas List 2002). However, the minimum overflight altitude within the Fox MOA throughout the year is 7000 feet above mean sea level (Dept. of the Air Force 1997). Military MOA flight activity over the majority of this area may not therefore be altered by this mitigation measure. In the Dall's sheep lambing area to the east of the Fox MOA, military aircraft are restricted to flying 1000 feet above ground level from 1 May through 30 June (11th Air Force Noise/Flight Sensitive Areas List 2002). The third area mitigated for Dall's sheep is in the Yukon 1 MOA at the Cirque Lakes Lambing Area. The area mitigated is a 7 nautical mile radius area centered at 64º48'00"N, 143º45'00"W. Here military aircraft are restricted to flying 5000 feet above ground level from 10 May to 15 June (FAA Aeronautical Study 95-AAL-042NR, 11th Air Force Noise/Flight Sensitive Areas List 2002). Because the floor of this MOA is 100 feet above ground level at other times of the year (Dept. of the Air Force 1997), Dall's sheep in this area may be exposed to a significant change in flying activity during the 1 month mitigation period. A final mitigation measure, not focused on Dall's sheep but relevant to this study is the military overflight exclusion area over the Charlie River from April 15 to September 15. This area extends from the surface to 2,000 feet AGL 2 NM either side of the river centerline (FAA Aeronautical Study 95-AAL-042NR, ROD 1995).

IMPACTS OF OVERFLIGHTS ON WILDLIFE

Janssen (1980), as detailed in the final MOA Environmental Impact Statement (1995), identified three levels of potential noise effects on wildlife. Primary effects are direct impacts such as hearing loss, ruptured ear-drums or deafness. Secondary effects include physiological responses, behavior changes, interference with reproduction, and reduced ability to obtain adequate food, water or cover. Tertiary effects are changes in age and sex ratios, population declines, habitat abandonment, and potential species extinction. In this study, we focused on secondary and tertiary effects.

Noise from low-level and high-level military aircraft has the potential to significantly impact ambient noise levels. Of primary concern is the potential for flight activity over

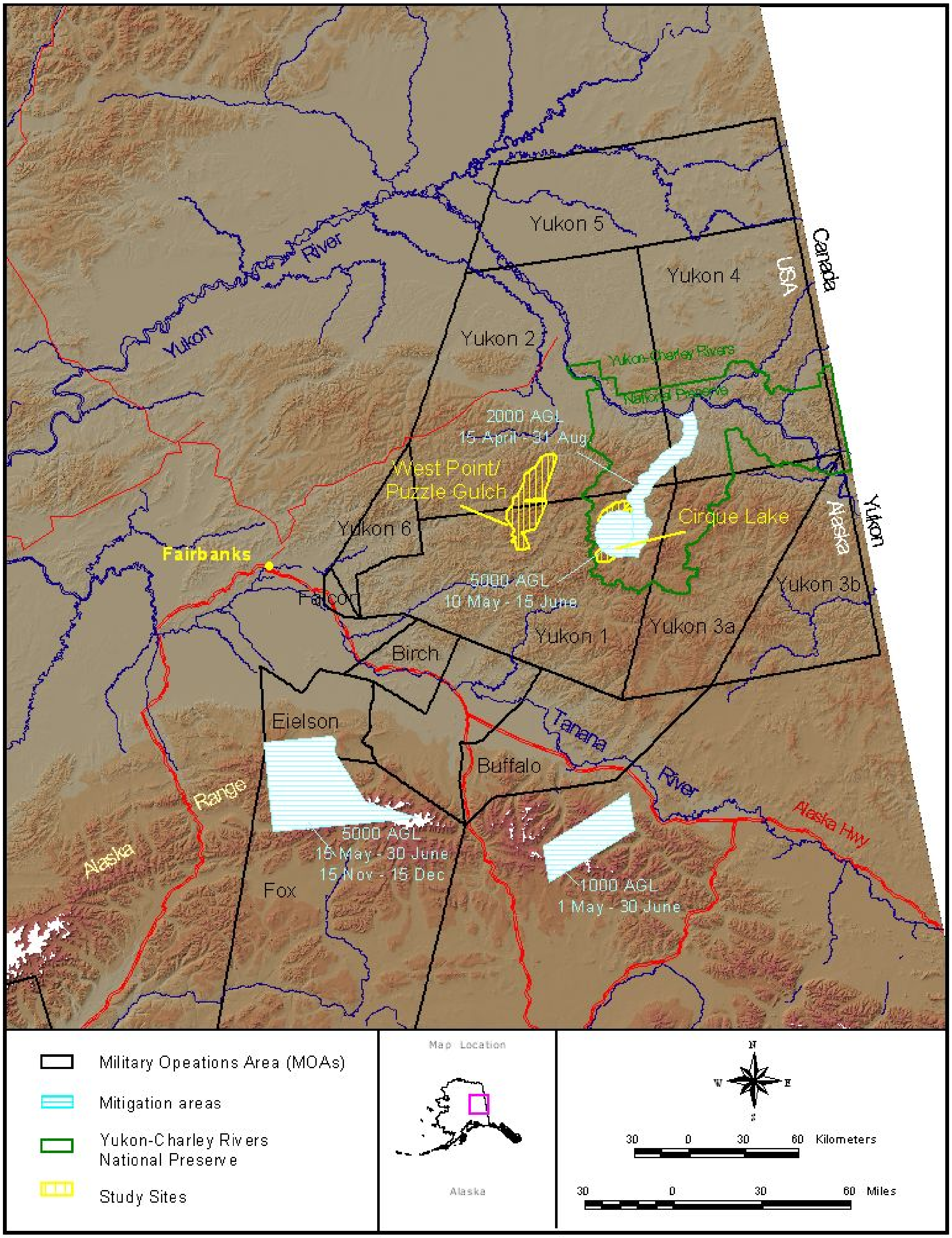


Figure 2. Location of Military Operations Areas (MOAs) in interior Alaska, 1998. Within the MOA structure some areas are mitigated for potential impacts of low-level military aircraft on Dall's sheep populations. Two study sites were selected for studying potential impacts. One area (Cirque Lake) is a mitigated sited and the second (West Point/Puzzle Gulch) is not.

wildlife to cause physiological and/or behavioral reactions that reduce the animals' fitness (National Park Service 1994). The way in which animals respond to overflights could interfere with raising young, habitat use, and physiological energy budgets (National Park Service 1994). Effects of overflights could be either chronic or acute. Chronic stress can compromise the general health of the animal and can be difficult to detect. Acute responses, such as startle and panic behavior, occur in most wildlife species evaluated at noise levels greater than 95 decibels (dB) (Dept. of the Air Force 1992). Noise events of this magnitude that are produced by military jet aircraft are typically short in duration and are essentially instantaneous events (Dept. of the Air Force 1992). Wildlife near and under these types of overflights are unlikely to detect them until the aircraft is above or past them. This activates the sympathetic nervous system (Moller 1978) causing a "startle" effect (Dept. of the Air Force 1992). In interior Alaska, maximum noise levels between 73 to 118 dB can be expected from routine low-level training operations (Dept. of the Air Force 1995).

Disturbance by human activity affects wildlife by increasing the energy invested by an individual in antipredator behavior (Berger et al. 1983). Both predation and disturbance can indirectly affect population dynamics by increasing energetic costs. Costs may include: 1) escape behavior (running or moving to different areas), 2) reduction in foraging efficiency by increasing vigilance behavior or by forcing individuals to use habitats in which safety is greater but forage quantity and quality are reduced, 3) interruption of maintenance activity such as feeding or ruminating, 4) increased exposure to natural predators, and 5) higher heart and metabolic rates. These costs could reduce reproductive success of individuals and lead to population declines.

Of the studies done on other taxa, perhaps studies on bighorn sheep (*Ovis canadensis*) are most applicable to Dall's sheep since they are of the same genus (*Ovis* spp.). Krausman and Hervert (1983) found that bighorn sheep did not respond to overflights of a Cessna 172 or Cessna 182 above 100 m (330 feet) but would leave areas when overflown by aircraft below 50 m (165 feet). Stockwell et al. (1991) found that in a situation with intense helicopter activity, bighorn sheep foraged less efficiently in the presence of helicopters than in the absence of helicopters. Bleich et al. (1994) observed that bighorn sheep overflown by helicopters during wildlife surveys exhibited marked responses in movement when compared to undisturbed animals. In addition, they found that reactions to overflights during spring were greater than at other times of the year and this response did not vary by sex. Since male and female wild sheep are spatially segregated for much of the year, this final result is particularly interesting. Bleich et al. (1994) suggest that bighorn sheep did not habituate to numerous helicopter overflights and they noted the potential for disturbance effects to be "exacerbated for animals living in heterogeneous environments, where critical resources are limited and widely distributed: mountain sheep are an excellent example of such a species".

Physiological responses to aircraft overflights have also been investigated for bighorn sheep by examining heart rates. Weisenberger et al. (1996) documented an increase in heart rate for bighorn sheep exposed to simulated military jet aircraft overflights in a laboratory setting. During the summer, heart rate was higher during the overflight event and 3 minutes after the overflight than it was before the event. In the spring, heart rate was only elevated during the overflight event. Krausman et al. (1998), examined heart rates and behaviors in semi free-ranging bighorn sheep exposed to overflights of F-16 aircraft. These authors found that heart rates could be more easily explained by animal activity than by the occurrence of an overflight event. Behavior during this study was also not altered by overflights. Both Weisenberger et al. (1996) and Krausman et al. (1998) conclude bighorn sheep habituate to overflight activity and suggest that bighorn sheep are unlikely to be adversely effected by military overflight.

Data on the impacts of military aircraft on Dall's sheep are nonexistent (Dept. of the Air Force 1995, Dept. of the Air Force 1992) and are mostly anecdotal for civilian fixed-wing aircraft (Anderson 1971, Linderman 1972, McCourt et al. 1974, Nichols 1972). For Dall's sheep, impacts of overflights are best documented for helicopters. Lenarz (1974) in Canada documented reactions of 49 groups of Dall sheep to helicopters flown at horizontal distances of 300 –500 ft. Thirty six percent of these sheep had a strong panic response, 49% had moderate reactions and 13% exhibited no reaction. Lenarz (1974) observed ewes to be more reactive than rams. Sheep in this study had been extensively overflown for 2 years prior to this study and the extent of reaction indicates no habituation was occurring for low-level helicopter overflights. Dall's sheep reactions to civilian aircraft in Atigun Gorge, Alaska varied considerably, with the most severe reactions occurring in response to helicopters (Anderson 1971). Sheep in this study appeared to be more easily disturbed while at mineral licks. Feist et al. (1974) noted that helicopters flown at altitudes of up to 1500 feet above ground level and horizontal distances of up to approximately 1 mile caused sheep to run.

Most recently, Frid (1994, 1997, 2003) examined the impacts of helicopters on Dall sheep in southwest Yukon, Canada. Sheep were observed to leave an area when disturbed by helicopters and initiated responses to aircraft when the helicopter was 2.2 $\pm$ 0.83 km (1.4 $\pm$ 0.5 miles) distant (n=9). During the summer of 1997, Frid (2003) found that the probability of a sheep reacting to an overflight was related to directness of approach of helicopters and the elevation of the approaching aircraft. Factors that contributed to the probability and severity of a response included group size, number of lambs in the group, and distance to escape terrain. Sheep would escape (move in response to the helicopter) farther if terrain features were such that a helicopter could surprise the animals by suddenly appearing or becoming audible.

In summary, the speed of military aircraft creates the potential to suddenly overtake Dall's sheep and possibly provoke a startle response. The slower speeds of civilian aircraft may enable sheep to locate the source and direction of the disturbance while the aircraft is still distant and may allow sheep to respond less strongly to the stimulus. Low-altitude jet aircraft flights would expose Dall's sheep to very short term, high intensity sounds and a noise profile different from civilian helicopters and fixed wing aircraft (Dept. of the Air Force 1995). Short term or acute responses to military aircraft overflight may include changes in movement, activity, or behavior in Dall sheep. Longer term or chronic responses brought about by repeated exposure to military aircraft overflights may also include changes in movement, activity, behavior, habitat selection and use, reproduction, mortality and population levels. The manner in which an organism responds to overflight activity depends on the life-history characteristics of the species as well as habitat type and previous exposure to aircraft (National Park Service 1994). Therefore, conclusions based on civilian aircraft may be in error when extrapolated to military aircraft and reactions of other species may differ from those of Dall's sheep. One goal of wildlife managers in the state of Alaska is to ensure long-term viability of wildlife species. The final Environment Impact Statement, Alaska Military Operations Areas (1995), indicates little is known regarding the impacts of military overflight activity on Dall's sheep. To address these issues, research was needed to specifically examine the impacts of military overflight activity on Dall's sheep. Better scientific information would allow the Air Force to accurately assess potential impacts for future Environmental Impact Statements and Environmental Assessments and would allow assessment of current and potential mitigation measures.

STUDY SITE SELECTION

Two study sites were selected for examining the effect of military overflight events, Cope Thunder excercises and mitigated airspace on Dall's sheep. The first site, Cirque Lakes, is located in Yukon-Charley Rivers National Preserve and is overlain by mitigated airspace (Fig. 2). The second site, West Point, is located approximately 35 km to the west of Cirque Lakes and has no associated mitigation measure. Both sites occur within the boundaries of the interior Alaska Yukon 1 and 2 MOAs. Study site selection was based on many criteria. Both sites exhibit similar environmental characteristics. Sheep populations in both areas are disjunct, occur at low densities, and occupy atypical sheep habitat. Topography in both areas is similar with a limited amount of rugged escape terrain occurring in relatively low, rounded mountains (Durtsche et al. 1990, Boudreau 1996). History of disturbance from civilian aircraft, hunting pressure and recreation pressure is similar and minimal (Boudreau 1996). Data are available for Dall sheep use in the Cirque Lakes area (Burch and Demma 1998, Burch and Lawler 2001) and in the West Point area (Durtshe et al. 1990). This combined with the patchy distribution of Dall sheep habitat in interior Alaska allowed for delineation of study areas. Observations by individuals familiar with the area indicate that West Point sees considerably more low-level military overflights than does Cirque Lakes, both in and out of the mitigated time period (Skip Ambrose, US Fish and Wildlife Service, pers. com.).

The final EIS (1995) projected mean daily military aircraft operations in the Yukon MOAs 1, 2, 3, and 4 to be 7 - 18 (Yukon MOA 4 and 1, respectively) aircraft operations per day in a routine flying day, and 164 - 206 (Yukon MOA 4 and 1, respectively) aircraft operations per day during MFE training. Supersonic activity in MOAs 1, 2, and 4 is authorized at or above 5,000 feet AGL or 12,000 MSL, whichever is higher (FAA Aeronautical Study 95-AAL-042NR). Subsonic flight activity in Yukon MOAs 1, 2, and 4 can occur as low as 100 AGL (FAA Aeronautical Study 95-AAL-042NR). Airspace in the Yukon 3 MOA is more complex. The Yukon 3 MOA is split into 3 separate MOAs. Yukon 3 High has a floor of 10,000 feet AGL and overlies the Yukon 3 Low MOAs. Yukon 3A Low and 3B Low are divided by a line that runs from the northeast corner of this MOA to the intersection with the northeast corner of the Buffalo MOA. Yukon 3A Low is the western portion of this MOA and has a floor 100 feet AGL. Yukon 3B Low, the eastern portion has a floor of 2000 feet AGL and is only used during MFEs. Supersonic activity is authorized in the Yukon 3 High MOA but not in the Yukon 3A Low or 3B High MOAs (FAA Aeronautical Study 95-AAL-042NR).

GOALS AND OBJECTIVES

This project was initiated to determine the effects of military overflights on Dall's sheep and the effectiveness of the mitigation plan. We addressed this goal by examining trends in population levels of Dall's sheep in some areas under the interior Alaska MOA airspace. We looked at Dall's sheep productivity and survival rates in some interior Alaska MOAs areas. Dall's sheep behavioral reactions to military overflights were investigated as were Dall's sheep daily movements, home range size, and habitat use. Dall's sheep/military overflight relationships were investigated by comparing high intensity periods of military overflights (MFEs) with low intensity periods of military overflights (routine flying days), and by comparing areas with different overflight and mitigation histories. Responses to specific overflight events were examined by comparing the proximity of an overflight and the sound level produced by the overflight. Specific objectives are:

> 1) Identify areas of use by Dall's sheep in Yukon MOAs 1 and 2 (areas where there is considerable low-level aircraft activity).
>
> 2) Examine trends in Dall's sheep populations in Yukon MOAs 1 and 2.
>
> 3) Examine reproductive success, and survival of Dall's sheep at 2 study sites within the MOA structure. One study site is mitigated for low-level military overflights and the other is not.
>
> 3) Describe and compare Dall's sheep relative activity, feeding efficiency and behavior in relation to Cope Thunders, mitigation measures, the frequency of overflight events, the proximity of the overflight event, and the sound level of overflight events.
>
> 4) Compare Dall's sheep daily movements, home range size, and habitat use and characteristics in relation to Cope Thunders, mitigation measures, and frequency of military overflight events.

Byproducts of achieving the above objectives include an understanding of the timing of seasonal shifts in habitat use and life stages associated with these shifts in interior Alaska, and characteristics of Dall's sheep habitat in interior Alaska.

Project goals and objectives, as well as time, money, and personnel dictate which questions are most appropriate to pursue and the methods used to pursue them. In this instance, we collected data on sheep movement, relative activity, and habitat use year round but focused behavioral and aspects of our study to those times of the year in which responses were expected to be the most evident. Logically, this was immediately before and during Cope Thunders, when flying activity was the greatest.

Potential exists for differences in response to overflight activity based on sex of the animal. Dall sheep are sexually segregated for much of the year. Bleich et al. (1997) found that male and female mountain sheep select for different habitat variables. Female sheep and their lambs occupied habitat with fewer predators and greater opportunities to avoid predation than did the larger body size, mature rams. Rams selected areas with superior nutritional qualities and presumably, exposed themselves to greater predation risk. Differences in habitat choices and behavior between sexes have the potential to obscure differences in responses to military overflight activity. Large sample sizes would be required to test for effects of disturbance on each sex of Dall sheep. We eliminated this problem by limiting our study to ewes and their lambs.

CHAPTER 1: Trends in Dall's sheep populations in military overflight areas mitigated and not mitigated for potential negative impacts

INTRODUCTION

Large remote landscapes are a scarce resource and are in demand from sources as diverse as wildlife species and the United States Air Force (USAF). Interior Alaska is such a place. In 1976, large portions of the airspace in eastern Interior Alaska were designated as "special use" for military operation areas (MOAs). Within these areas, the USAF, as well as allies of the United States, practice air combat, and formation and aerobatic training (Final Alaska MOA EIS Record of Decision 1997). Since 1976, expectations of the military and a variety of technological and other changes created a need to modify the existing airspace arrangement and an environmental impact statement (EIS) was written (Department of the Air Force 1995) followed by a Record of Decision (Final Alaska MOA EIS Record of Decision 1997). The Record of Decision (1997) established a set of mitigation measures intended to minimize the impacts of military jet overflights on people and animal within the MOA structure. The 11th Air Force Noise/Flight Sensitive Areas List (2002) specifies how these mitigation measures will be implemented and is updated on a periodic basis. Protection of Dall's sheep in interior Alaska is the focus of 3 of mitigation measures.

Mitigation measures directed at Dall's sheep focus on the lambing season and the rut. In the Alaska Range, mitigation measures for lambing sheep are in place from 1 May - 30 June. Military aircraft are to maintain a floor of 1,000 feet above ground level (AGL) or 5000 feet AGL depending on location (Fig. 1.1). During the rut, military aircraft are restricted to flying above 5000 feet AGL in the mitigated area under the Fox MOA from 15 November - 15 December (Fig. 1.1). In the Yukon-Tanana Uplands, military aircraft are to maintain a floor of 5,000 feet AGL from 10 May - 15 June over the Cirque Lake lambing area (FAA Aeronautical Study 95-AAL-042NR, Dept. of the Air Force 2002). Because the floor of this MOA is 100 feet above ground level at other times of the year, as opposed to the 7,00 foot AGL ceiling in the Fox MOA (Dept. of the Air Force 1997), Dall's sheep in this area may be exposed to a significant change in flying activity during the 1 month mitigation period. Because Dall's sheep mitigation measures in the Yukon-Tanana Uplands are some of the most restrictive, this area is the logical choice for initiating a study to examine the effectiveness of the mitigation measures. An additional mitigation area, the Charley River, partially overlaps the Cirque Lake lambing area. Although not specifically directed at Dall's sheep, sheep in this area may still benefit. The Charley River is mitigated 2 nautical miles either side of the riverbank from the surface to 2000 feet AGL from 15 April to 31 August (Dept. of the Air Force 2002).

Dall's sheep populations are found in disjunct pockets throughout the Yukon-Tanana uplands. Sheep occur in the limited patches of steep rocky alpine habitat interspersed throughout the dominant boreal forest (Durtsche et al. 1990, Boudreau 1996). Interchange of individuals between habitat patches has been documented in a few instances (Durtshe et al. 1990, Burch and Lawler 2001). History of disturbance from civilian aircraft, hunting pressure and recreation pressure is minimal (Boudreau 1996).

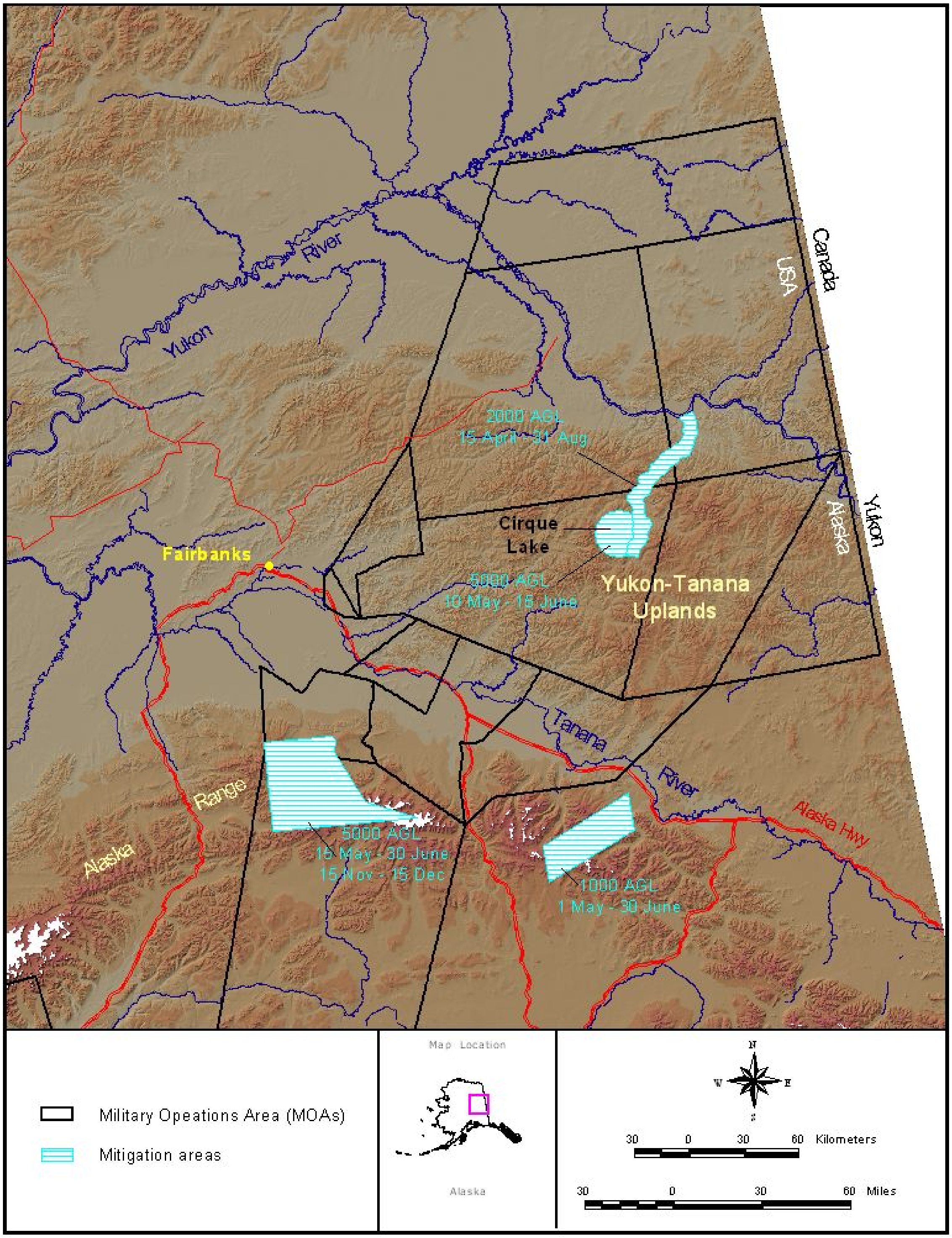


Figure 1.1 Military Operations Areas (MOAs) in Interior Alaska. Of the areas mitigated for protecting Dall's sheep, the mitigation around Cirque Lake is the most restrictive with an exclusion area for military jets from the surface to 5,000 feet above ground level (AGL) from 10 May – 15 June.

Dall's sheep in the Yukon-Tanana Uplands have been living with the MOAs since their creation in 1976. The nature of the flying has changed however, as have the aircraft. In the mid 1980s, F-15s and A-10 military aircraft replaced the F-4s that had been stationed in Alaska. In 1991, F-16s were added to the air fleet. In 1995, the current pattern of mitigation was put into place (Department of the Air Force 1995). It is a goal of this document to evaluate the effectiveness of the Cirque Lake Dall's sheep mitigation on sheep population levels and trends in comparison to areas within the Yukon-Tanana Uplands with no mitigation.

STUDY AREA

The study area was eastern interior Alaska in the Yukon-Tanana Uplands and is centered in Yukon-Charley Rivers National Preserve. The most prominent feature of this area is the Yukon River which flows across the northern portion of this region (Fig. 1.2). Elevations range from 305 m above sea level to 2000 m above sea level. Climate is semi-arid continental. Climate summaries are available from 2 weather stations in the vicinity of the study area (both are approximately 115 km from the center of the Cirque Lake survey unit). At Circle, Alaska, north-west of the study area, mean annual precipitation from 1957 – 1999 was 20.7 cm. Mean daily maximum temperatures ranged from 22.8°C in July and –22.9°C in January (National Weather Service). At Eagle, Alaska, east of the study unit, mean annual precipitation from 1957 – 2002 was 30.4 cm. Mean daily maximum temperatures ranged from 22.6°C in July and –19.7°C in January (National Weather Service). Topography in the study area is rolling forested areas with rugged alpine tundra areas interspersed throughout.

The study area is within the subarctic boreal forest zone. Dominant tree species include black spruce (*Picea mariana*) in low-lying areas, and white spruce (*Picea glauca*), aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) in better drained locations. Above 600 m, tundra vegetation dominates. Plant species in these alpine areas are typical tundra plants and include dryas (*Dryas spp.),* dwarf willow (*Salix spp.*), and bearberry (*Arctostaphylos spp.*) The Yukon-Tanana Uplands were largely unglaciated throughout the Quaternary and as a result, steppe vegetation persists on south facing bluffs along riversides. In some instances, such as along the Charley River, these south facing bluffs are heavily utilized by Dall's sheep. More detailed descriptions of the physiography and vegetation of this area can be found in Roland (1996), Swanson (1999), and Ducks Unlimited (1998).

METHODS

Aerial Surveys and Study Area

Observers counted Dall's sheep from a helicopter in 8 study units within the interior Alaska, Military Operations Areas in June or July during 1997 – 2002 (Fig. 1.2). Not all units were surveyed in 2000 as poor weather prevented the completion of the survey. Some sheep counts were available prior to 1997 (Appendix A). In most cases, this data were not used in analysis due to uncertainties regarding the area covered by the survey, the time spent surveying (sampling intensity), large gaps between years in data sets, and differences in timing of the survey. From 1997 – 2002, the same 2 individuals acted as observers for the 8 units used for most analysis with 1 exception. In 2000, a year

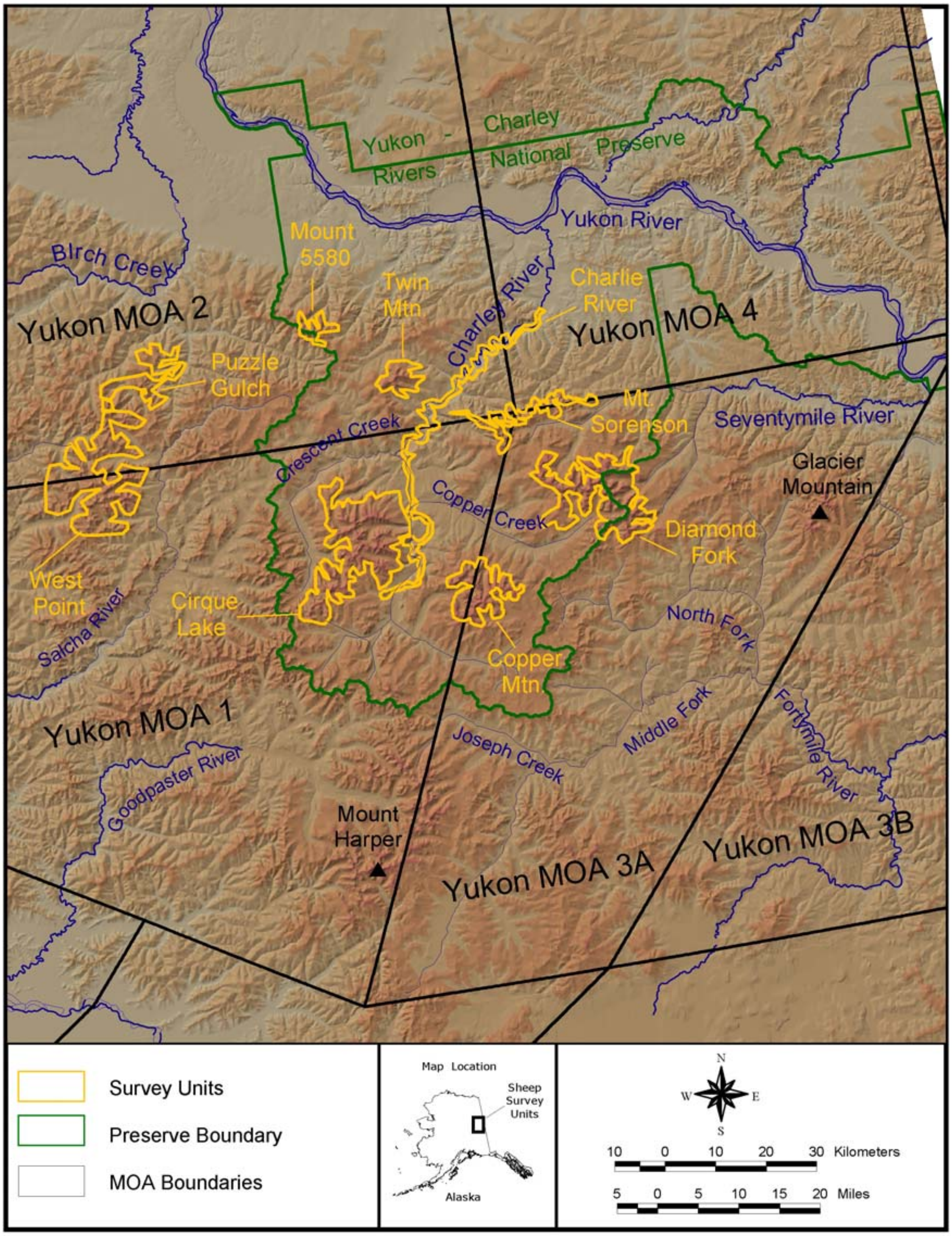


Figure 1.2. Dall's sheep survey units in the Yukon-Tanana Uplands, eastern interior Alaska. Units were surveyed in mid-summer from 1997-2002 using a helicopter.

when the survey was only partially completed, only 1of the 2 participated. In 2 of the survey units (Cirque Lake and Mount Sorenson) data collected from 1993 through 1995 is consistent with the areas and the survey effort of the 1997-2002 data set but the observers collecting the data differed. Although one observer during these 3 surveys was the same individual, the second observer was a different individual each year. Different types of helicopter have been used during surveys. Before 1998, surveys were conducted with a Bell 206 Jet Ranger, or a Hughes 500 and from 1998 – 2002, surveys were conducted with a Robinson R-44.

Dall's sheep were counted in study units by flying contours around terrain features (Burch and Lawler, 2001). Typically, 2 – 3 passes were made over a given feature. Observed sheep were classified as rams, ewe-like, yearling, or lambs. Rams included all animals with greater than 1/4 curl horns. Rams $\leq$ 1/4 curl and all adult ewes were categorized as "ewe like" because of the difficulty in distinguishing between these 2 classes. Yearling ewes were categorized as such based on size differences relative to lambs and adult ewes as well as horn characteristics (Geist 1971). Yearling rams were likely classified primarily as "ewe like" because of the similarity in appearance in yearling rams and adult ewes. In some situations, however, yearling rams with small bodies and small horns may have been classified as "yearlings". Lambs of the year were conspicuous because of their small size and horns. Locations of sheep were marked on 1:63,360 scale USGS maps and numbers and sex and age classifications were recorded. This information was used to reduce the potential for "double counting" sheep during the survey. Flight lines of areas surveyed were recorded as were survey times.

Survey units and areas surveyed for Dall's sheep were areas known to consistently harbor sheep. These areas were flown until observers and the pilot felt comfortable that all probable sheep habitat had been surveyed. Partially due to different environmental factors, this comfort level varied from year to year. With experience, we were also able to eliminate improbable sheep habitat from the survey. Therefore, the speed at which these units were surveyed varied as did the area. We used flight time as a measure of survey effort as this measurement includes aspects of both flight speed and area. To calculate sheep densities, we used the perimeter of our flight path during the 1999 survey as this area is a good approximation of known sheep habitat in the area. All sheep observed during the surveys in all years fell within the perimeter of these boundaries with 2 exceptions. Both exceptions occurred to the south of the 1999 Twin Mountain survey area. In 1997, 2 ewes and 2 yearlings were observed south of the boundary and in 1998, 8 ewes, 2 yearlings and 4 lambs were observed south of the boundary.

We evaluated sheep sightability and developed correction factors using radiocollared sheep and mark-resight methodology (Furlow et al. 1981, Leslie and Douglas 1979, 1986, Neal et al. 1993). Two separate studies involving radiocollared sheep have occurred within the study units during years in which aerial surveys were conducted (Burch and Lawler 2001). As a result, the number of radiocollars within our study area has varied (range = 8 - 24 animals), as has the distribution of collars. Radiocollared animals in 1997 were evenly distributed throughout the units surveyed with the exception of West Point/Puzzle Gulch where there were no radiocollared sheep. During subsequent years, radiocollared sheep have been scattered throughout the survey units but have been most concentrated along the Charley River and Cirque Lake units, and in the West Point/Puzzle Gulch area. A fixed-wing aircraft (Piper Super Cub, PA-18) was used to locate all radiocollared sheep within 1 day of the helicopter sheep population survey and we assumed a closed population (no births, deaths, immigrations, emigrations during the 24 h period; Neal et al. 1993). Coordinates of radiocollared sheep were noted during the helicopter aerial survey and compared to the locations recorded by the fix-winged aircraft. Only radiocollared sheep located within the perimeters of the study units were used in estimates of sheep populations in the survey units and only radiocollared sheep located within the perimeters of the study area were used in estimates of sheep populations in the study area.

Of the 8 study units surveyed within the MOA structure, 2 are mitigated for low-level military overflights (Fig. 1.2). Beginning in 1995, military aircraft are to avoid the Cirque Lake Dall's sheep lambing area from the surface to 5000 feet AGL (above ground level) from 10 May to 15 June. The area to be avoided is a 7 nautical mile radius area (Fig. 1.1) centered at 64°48'00"N/143°45'00"W (11th Air Force 1997). Mitigation for the Charley River is an avoidance area 2 nautical miles either side of the riverbank from the surface to 2000 feet AGL from 15 April to 31 August. The mitigated area extends from 64°41'00"N/143°38'00"W to 65°19'00"N/142°46'00"W (11th Air Force 1997).

DATA ANALYSIS

Sampling effort (survey time and area per unit) varied from year to year. In each year, however, effort was spent in each unit to complete what the observers felt was a thorough survey. We tested the assumption that the number of sheep counted during a survey was not affected by the sampling effort during surveys using a general linear model (GLM: SPSS 9.0 1999). Because different sexes may vary in sightability (McCorquodale 2001), we separated total number of sheep into "ewe groups" and rams. Yearlings and lambs were included with ewe group totals because of autocorrelation considerations (it is unusual to observe lambs or yearlings without ewes). Survey units varied considerably in complexity and character. Some had substantial tree cover whereas others were devoid of trees. Differences in terrain complexity may result in differences in the amount of survey time expended in an area. For this reason, we analyzed units separately.

Trends in Dall's sheep population numbers following the initiation of mitigation measures within the MOA structure were examined using repeated-measures general linear model. For analysis, we lumped ewe, lamb, yearling and ram numbers into "total sheep" to reduce the number of dependent variables within our model. Seven survey units were classified into 1 of 3 categories: 1) no mitigation (n = 5); 2) Cirque Lake mitigation (n = 1); 3) Charley River mitigation (n = 1). Sheep surveys from 1997 – 2002 were used for analysis with the exception of 2000 (n = 5). The 2000 survey was excluded due to missing data. An 8th survey unit (West Point/Puzzle Gulch) was also excluded from this analysis because of missing data. Data used in repeated-measures analysis were examined for sphericity with the Machly sphericity test. Results of all statistical tests were considered significant when $P \leq 0.05$.

We tested for differences in number of rams and total number of sheep in ewe groups before and after the initiation of mitigation measures at a mitigated area (Cirque Lake) and non-mitigated area (Mount Sorenson) with a multivariate analysis of variance (MANOVA). These units were chosen for analysis because they are the only 2 units for which we have more than 2 surveys prior to 1995, the year mitigation measures were started (Appendix A). When MANOVA detected differences in number of rams and number of sheep in the ewe group category, we used analysis of variance (ANOVA) to identify variables that differed.

The disjunct nature of the sheep habitat in the Yukon-Tanana Uplands suggests numerous sheep populations isolated by large expanses of unsuitable habitat. Evidence from the aerial sheep surveys, however, show great variability in numbers and composition of sheep populations that are inconsistent with reasonable mortality and production rates in closed populations suggesting interchange between these populations. Evidence from radiocollared sheep also suggested interchange between these populations (Burch and Lawler 2001). For this reason, following the examination of individual units, we looked at trends in sheep population in the Yukon-Tanana Uplands using a general linear model by combining sheep counts from multiple units into a yearly sheep population index. Five years of data were available for analysis by combining data from the Charley River, Cirque Lake, Mount 5580, Twin Mountain, Mount Sorenson, Copper Mountain, and Diamond Fork survey units. Known sheep areas within the Yukon-Tanana Uplands excluded from this analysis because of insufficient data, non-compatible or non-existent data were West Point, Puzzle Gulch, Glacier Mountain and Mount Harper (Fig 1.1).

The precision of sheep surveys since 1997 was evaluated using mark-resight methods (White and Garrott 1990, Neal et al. 1993). We used the Lincoln-Peterson estimate to evaluate sheep numbers within units surveyed (Chapman 1951; Seber 1982, White and Garrott 1990) using the number of radiocollared sheep and total number of sheep observed during the helicopter survey. In addition, we estimated population variance and constructed 95% confidence intervals for yearly population estimates (Seber 1982, White and Garrott 1990) in 7 survey units. Sheep counts and radiocollared sheep at West Point/Puzzle Gulch were not included in mark-resight population estimates because data for this unit was only available for 3 years.

RESULTS

Survey Effort

Considerable variation existed in survey effort, both within survey units (Table 1.1) and between survey units. Within survey units, there was a tendency for smaller units and units in which less time was spent surveying to have greater variation in survey times (Table 1.1). The exception to this trend was Mount 5580 which had both a low coefficient of variation (9%) as well as a small mean survey time (0.5 h). Of all units surveyed, the most effort per unit area was directed toward Copper Mountain and the least was directed at the Charlie River (Table 1.1). Survey effort was over 80% greater per unit area covered at Copper Mountain in comparison to the Charley River.

Table 1.1. Summary statistics for survey effort of summer aerial Dall's sheep surveys in interior Alaska, Military Operations Areas from 1997 – 2002.

Unit	Area (km^2)*	# of Surveys	Mean Survey time (h)	Coefficient of Variation	km^2 surveyed/ hour
Diamond Fork	398	5	2.3	0.16	173
Charley River	211	6	1.7	0.32	124
Cirque Lake	553	8	2.9	0.18	191
Copper Mountain	227	5	1.0	0.35	227
Mount 5580	69	6	0.5	0.09	138
Mount Sorenson	218	8	1.3	0.14	168
Twin Mountain	120	6	0.8	0.32	150
West Point/Puzzle Gulch	620	3	2.9	0.03	214

* Area was calculated from the area flown during the 1999 sheep survey.

Although variable amounts of effort were spent surveying individual units, we were not able to attribute variation in the number of sheep counted in ewe groups and ram groups within a unit to survey effort (Table 1.2). Only at Mount 5580 did we approach a significant relationship ($P = 0.078$). Because none of the MANOVA results were significant, follow-up univariate tests for the effect of survey effort on number of sheep counted in ewe groups and the effect of survey effort on number of sheep counted in ram groups were not examined.

Table 1.2. MANOVA results investigating survey effort and its effect on Dall's sheep counts in interior Alaska, Military Operations Areas. Sheep were categorized into 2 groups. Ewes, lambs and yearlings were typically observed together and were considered one group and rams were considered a separate group.

Unit	Sample Size (*n*)	*df*	*F**	*P*
Diamond Fork	5	2, 2	1.246	0.455
Charley River	6	2, 3	0.401	0.701
Cirque Lake	8	2, 5	0.417	0.680
Copper Mountain	5	2, 2	0.740	0.575
Mount 5580	6	2, 3	6.718	0.078
Mount Sorenson	8	2, 5	2.149	0.212
Twin Mountain	6	2, 3	0.363	0.722
West Point/Puzzle Gulch[a]	3			

* Pillai's Trace statistic.

[a] Small sample size ($n = 3$) precludes analysis.

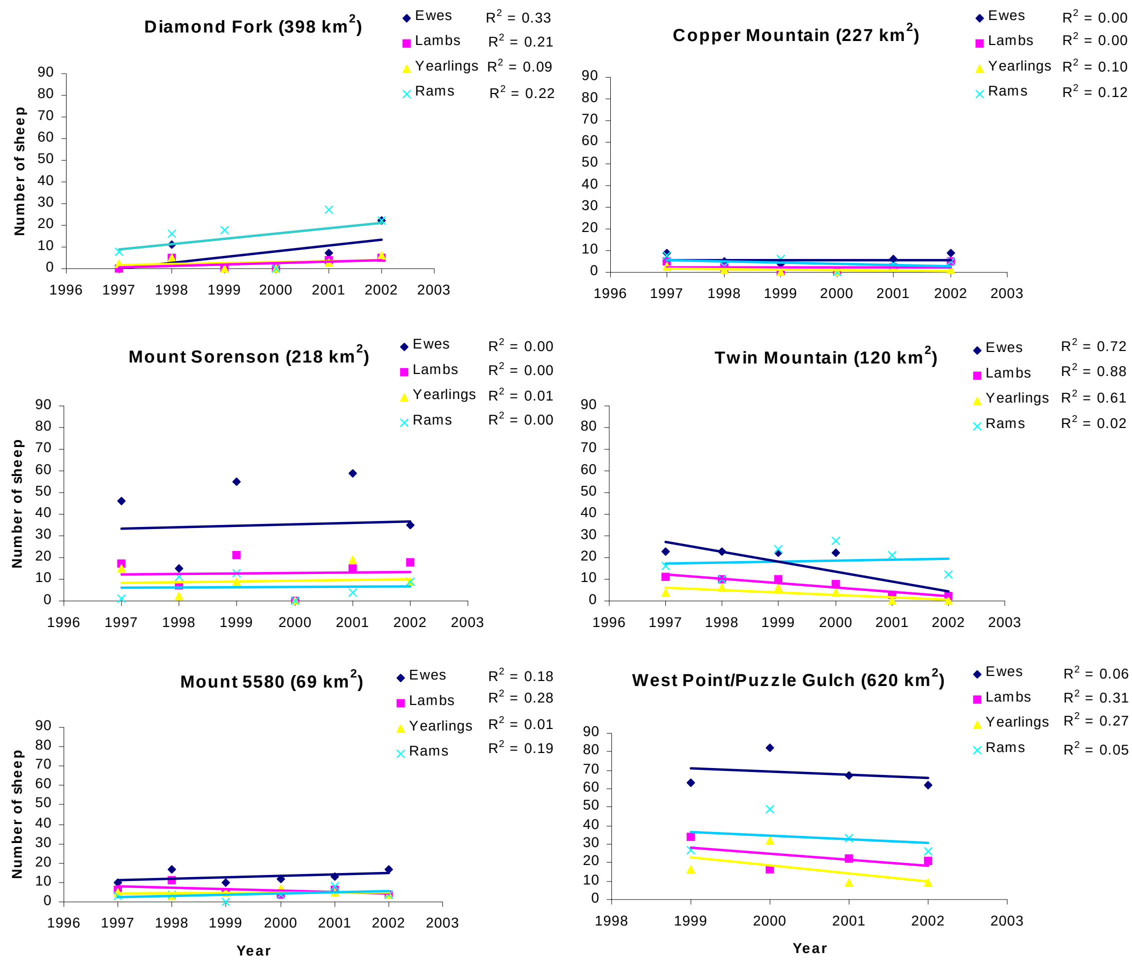
Trends in Dall's sheep numbers in aerial survey units

Since 1997, both the total number of sheep counted as well as number counted in each sex and age class varied considerably within units and this was true of both the mitigated as well as the unmitigated areas. (Fig. 1.3; Appendix A). This variation was considerable as illustrated by the number of sheep observed while surveying the Mount Sorenson area. Observed sheep declined by 44% from the 1997 survey compared to the 1998 survey, and this was followed by a 180 % increase in observed sheep when comparing the 1998 survey to the 1999 survey (Fig 1.3). Coefficients of variation for observed Dall's sheep in individual units ranged between 55% and 20% for Diamond Fork and Mount 5580, respectively. Densities of sheep also varied considerably between units with estimated sheep densities of up to 0.52 sheep per km^2 during 1999 and 2000 in the Twin Mountain unit and as few as 0.03 sheep per km^2 during 1997 in the Diamond Fork unit (Fig. 1.4). Mean Dall's sheep densities for all units over this time period was 0.18 [95% confidence level = 0.16, 0.19] sheep per km^2 of areas surveyed. From 1997 through 2002, no differences in trends in Dall's sheep numbers within the interior Alaska MOA were identified for those areas mitigated and not mitigated for low-level military overflights with a repeated-measures general linear model (Pillai's trace: $F = 1.079$, $d.f. = 4, 2$, $P = 0.533$).

Trends in Dall's sheep populations before and after mitigation

MANOVA results indicated a significant difference in the number of rams and number of sheep in the ewe group category in the years before and after the initiation of the mitigation measures at Cirque Lake and Mount Sorenson (Pillai's trace; $F = 5.04$, $d.f. = 2, 18$, $P = 0.029$). In addition, there was a significant interaction between location (Cirque Lake or Mount Sorenson) and mitigation (before or after)(Pillai's trace $F = 4.91$, $d.f. = 2, 18$, $P = 0.020$). Sheep numbers increased at Mount Sorenson following the initiation of mitigation and sheep numbers at Cirque Lake stayed relatively unchanged. Examination of univariate results indicate that these differences were due to a significant difference in the number of sheep in the ewe groups ($F = 10.63$, $d.f. = 1, 22$, $P = 0.004$) but not in the ram groups ($F = 0.28$, $d.f. = 1, 22$, $P = 0.605$) before and after the initiation of mitigation measures. The univariate results for the location * mitigation interaction also support a difference in the number of sheep in the ewe group category ($F = 9.305$, $d.f. = 1, 22$, $P = 0.007$) and not the number of rams ($F = 1.982$, $d.f. = 1, 22$, $P = 0.175$). In general, following 1995 (the year mitigation measures were started), sheep numbers and sheep densities were higher at Mount Sorenson (unmitigated) in comparison to Cirque Lake (mitigated)(Fig. 1.3 and 1.4).

a) Non-mitigated



b) Mitigated

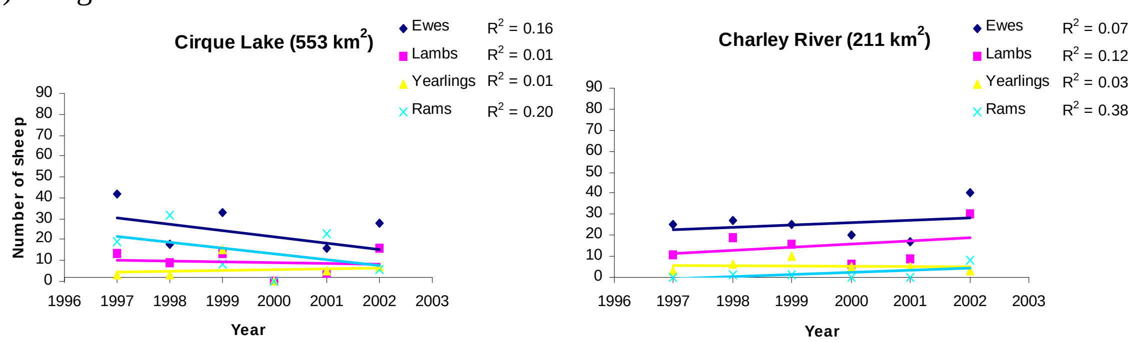
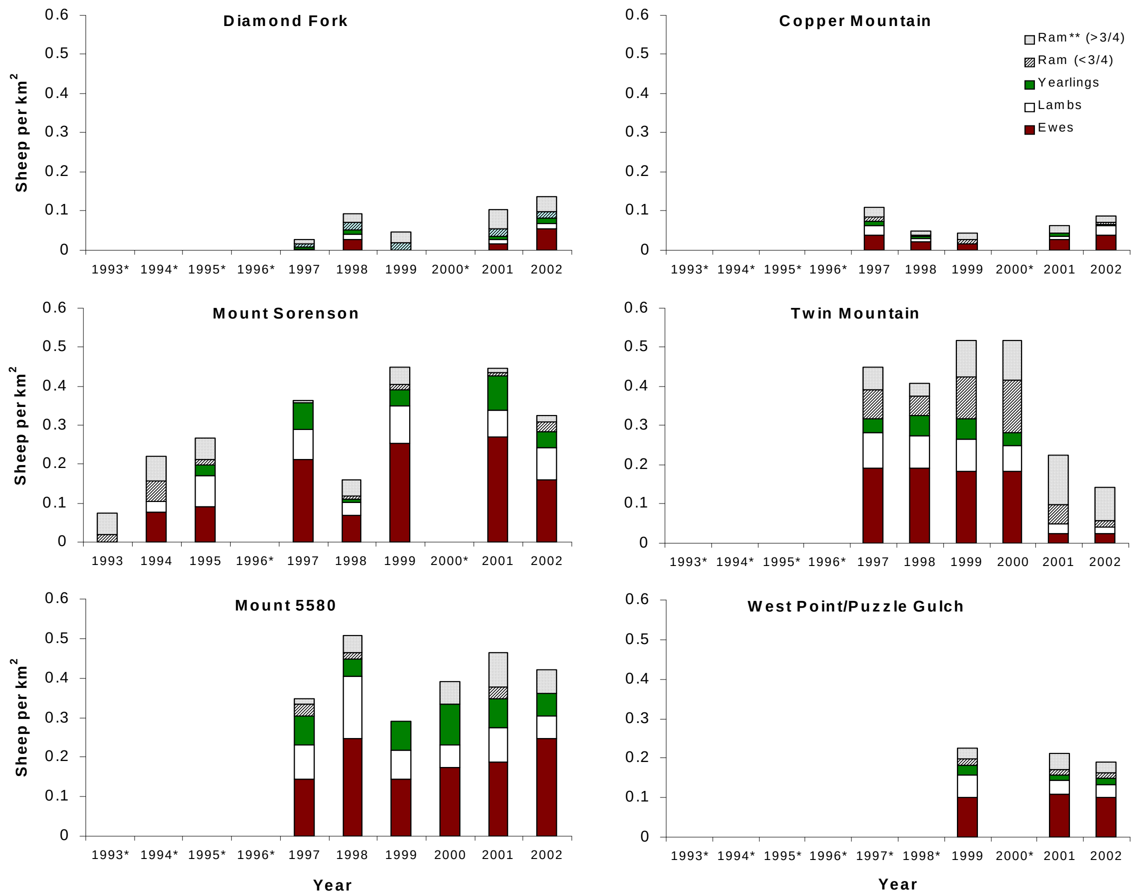
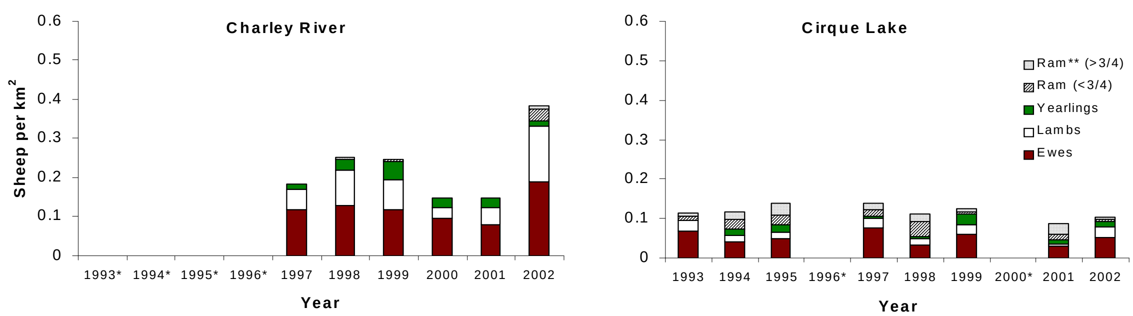


Figure 1.3. Counts of Dall's sheep in Interior Alaska Military Operations Areas. Some survey units may be exposed to low-level military jet overflights throughout the year (a) and others have seasonal mitigations (b). Military aircraft may fly as low as 100 feet above ground level but 10 May - 15 June, military jets must stay 5000 feet above ground level at the Cirque Lake area and 15 April - 31 August, military jets must stay 2000 feet above the Charley River area.

a) Non-mitigated



b) Mitigated



* No data colleced for this survey unit during this year.

** Includes 3/4 curl rams.

Figure 1.4. Densities of Dall's sheep in Interior Alaska Military Operations Areas. Some survey units may be exposed to low-level military jet overflights throughout the year (a) and others have seasonal mitigations (b).

Trends in Dall's sheep populations in the Yukon-Tanana Uplands

An examination of the sheep population in the Yukon-Tanana Uplands that included data from multiple survey units (see methods) did not indicate a significant trend in the sheep population from 1997 to 2002 ($F = 0.416$, $d.f. = 1, 4$, $P = 0.565$; Fig. 1.5). Mean (± SE) number of sheep observed during the 5 years of surveys was 308 (± 9.8) animals and there was little variability in this count from year to year (coefficient of variation = 7%).

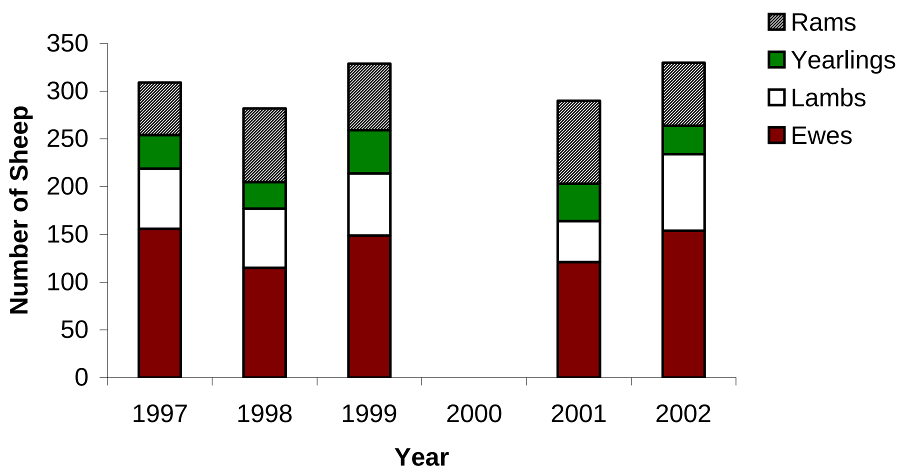


Figure 1.5. Numbers of Dall's sheep observed in 7 survey units within the Interior Alaska Military Operations Areas during summer aerial surveys, 1997-2002. A survey was not completed in 2000 due to poor weather conditions.

Precision of Dall's sheep surveys in the Yukon-Tanana Uplands

With the exception of 1998, sheep sightability was good (Table 1.3). The number of sheep counted during that survey however, was similar to other years (Fig. 1.5). Using the Lincoln-Peterson estimate to evaluate sheep numbers within units surveyed, we estimated a mean (±SE) of 365 (±23.5) sheep within the 7 surveyed units within Yukon-Charley Rivers National Preserve (Table 1.3). If 1998 is excluded from this analysis, the mean (±SE) estimate becomes 343 (±11.7). In some instances, radiocollared sheep were outside of survey units during the survey, but were still within the boundaries of Yukon-Charley Rivers National Preserve. Using these radiocollared animals allowed us to make an estimate of the sheep population within the preserve (Table 1.3). The mean (±SE) estimate of sheep within Yukon-Charley Rivers National Preserve was 389 (±31.0).

Excluding 1998 from this data sets result in a Yukon-Charley Rivers National Preserve estimate of 360 ($\pm$11.0) sheep.

Table 1.3. Sightability of Dall's sheep in Yukon Charley Rivers National Preserve, Alaska 1997 – 2002. Sightability is based on the number of radiocollared sheep observed during aerial surveys and population estimates within survey units and with the preserve are based on these sightability values.

	Year*				
	1997	1998	1999	2001	2002
Number of marked sheep	9	17	24	12	13
Number marked within surveyed units	8	15	22	12	13
Total marked sheep observed in surveyed units	8	9	20	10	12
Total missed in units	0	6	2	2	1
Total missed out of units	1	2	2	0	0
Total number of sheep observed	309	282	329	294	330
Population estimate in units	309	452	360	348	355
Variance in units	0	6743	483	1500	623
95% Confidence Interval	0	160.9	43.1	75.9	48.9
Correction Factor	1	1.6	1.1	1.2	1.1
Population estimate in Preserve	343	508	392	348	355

* A survey was not completed in 2000 due to poor weather conditions.

DISCUSSION

Although considerable variability has existed in the amount of effort spent surveying for sheep in the Yukon-Tanana Uplands, this variability does not appear to have affected the sheep counted in individual units (Table 1.1). This conclusion is supported by the lack of a relationship between survey effort and number of sheep counted (Table 1.2) as well as stability of the sheep count from 1997 – 2002 (Fig. 1.5). This is encouraging as it appears that varying survey time based on pilot and observer comfort level allowed for consistent survey results.

No differences in trends in the number of observed sheep between areas mitigated and not mitigated for low-level military aircraft were identified from 1997 – 2002. It is possible that trends in individual units were obscured by the amount of variation in counts from one year to the next. Another interpretation of this result is that any changes in trends caused by mitigation measures were realized in the 1st year they were implemented (1995) and current trends were established at that time. Alternatively, this result can be interpreted as no effect of mitigation measures on Dall's sheep population trends in the Yukon-Tanana Uplands. This latter explanation is supported by other evidence presented in this document such as population trends before and after the initiation of mitigation measures at Cirque Lake and Mount Sorenson.

The fluctuations in Dall's sheep numbers within individual units from 1997 – 2002 was surprising. Dall's sheep are typically thought to be highly traditional animals that show great fidelity to specific ranges at specific times of the year (Geist 1971, Nichols and Bunnel 1999). Results from the aerial surveys and radiotelemetry data (this study and Burch and Lawler 2001) indicate this is not the case in the Yukon-Tanana Uplands in early July as it appears sheep are regularly moving from one suitable patch of habitat to another. Therefore, long-term affects of mitigation measures at one site may be difficult to identify due to mixing of sheep from different survey areas. Alternatively, the mitigation of a small area, such as Cirque Lake, may be inappropriate as sheep in the Yukon-Tanana Uplands appear to be using habitat at a larger scale than the small patches (survey unit) of suitable habitat scattered through out the Yukon-Tanana Uplands or defined by the 7 nautical mile radius mitigation area. These movements do, however, emphasize the importance of travel routes between habitat patches. Knowledge of these routes is thought to be traditional with younger animals learning the routes from following older animals (Nichols and Bunnel 1999). Therefore, disruption of these routes would hinder exchange between areas of suitable habitat. Geist (1975) proposed this as an explanation for the lack of sheep in many apparently suitable areas.

We did identify a significant long term change in the number of sheep when comparing a mitigated site (Cirque Lake) to a non-mitigated site (Mount Sorenson). Specifically, the area that isn't mitigated for low-level military aircraft experienced an increase in the numbers of ewes, lambs and yearlings since the initiation of mitigations measures. This pattern is the reverse of what one would expect if population levels of Dall's sheep are positively affected by the presence of the mitigation measures. This supports the conclusions that there is no measurable effect of mitigation measures on population trends in the Yukon-Tanana Uplands.

The five year trend in Dall's sheep numbers in the areas surveyed in the Yukon-Tanana Uplands indicates a stable population of sheep. Due to differences in areas surveyed prior to 1997 it is difficult to know if the current population level is similar to population levels prior to mitigation measures 1995. Based on values calculated from the Lincoln-Peterson estimate and the confidence intervals constructed around these values, we can have a high degree of confidence that the majority of sheep in the area of interest are occurring in the survey units and that we are seeing the majority of sheep. Only during 1998 was there a problem with sheep sightability and this was likely due to problems with identifying marked animals (i.e., we missed seeing radiocollars on sheep) verses missing sheep in general because the total sheep count in that year was similar to other years.

In conclusion, aerial sheep counts provided a relatively consistent measure of Dall's sheep populations in the areas surveyed. Although population counts varied considerably within individual units, sheep population levels in the entire study area varied little (Fig. 1.5). There is no evidence that the current mitigation measures have altered Dall's sheep population trends in areas mitigated for military overflight activity in comparison to areas not mitigated. This conclusion is based on Dall's sheep counts conducted before and after the implementation of mitigation measures as well as population trends following the initiation of the measures. Movement of Dall's sheep between units, however, complicate this conclusion as negative effects in one area may be off-set by movement of sheep from less impacted areas. Finally, mitigation at one site (Cirque Lake) may be difficult to justify as this is not a closed population. Evidence suggests a large amount of movement of Dall's sheep between habitat pockets. Future consideration of Dall's sheep in this area should treat Dall's sheep in this portion of the Yukon-Tanana Uplands as 1 population (Fig 1.1).

SUMMARY

We evaluated sheep population levels and trends in areas mitigated for low-level military overflights in comparison to areas with no mitigation. The sheep population in the Yukon-Tanana Uplands was estimated using aerial surveys. Areas surveyed (units) were separated by atypical sheep habitat. From 1997 to 2002, the total number of sheep counted as well as number counted in each sex and age class varied considerably within units and this was true of both the mitigated as well as the unmitigated areas. No differences in trends in Dall's sheep numbers within units were identified for those areas mitigated and not mitigated for low-level military overflights. For two units for which we have an estimate of Dall's sheep numbers before and after the initiation of mitigation measure, sheep numbers increased at the non-mitigated site following the initiation of mitigation and sheep numbers at the mitigated site stayed relatively unchanged. Counts of all units did not indicate a significant trend in the sheep population from 1997 to 2002 in theYukon-Tanana uplands and there was little variability in the total count from year to year (coefficient of variation = 7%). There is no evidence that mitigation measures altered Dall's sheep population trends in areas mitigated for military overflight activity in comparison to areas not mitigated.

CHAPTER 2: Dall's sheep productivity, and survival rates in interior Alaska in mitigated and non-mitigated military overflight areas

INTRODUCTION

The Yukon-Tanana Uplands of interior Alaska are overlain by airspace that is designated as a military operations area (MOA). Military aircraft from the United States Air Force (USAF) and its allies utilize this airspace for air combat training, fighter intercept training, basic fighter maneuvers, and low altitude fighter operations (Department of the Air Force 1995). Dall's sheep (*Ovis dalli*) also occupy the Yukon-Tanana Uplands. Aircraft have been shown to have varying impacts on wild sheep (Krausman and Hervert 1983, Lenarz 1974, MacArthur et al. 1979, Stockwell et al. 1991, Krausman et al. 1993, Bleich et al. 1994, Weisenberger et al. 1996, Krausman et al. 1998) leading to concerns of potentially negative impacts on Dall's sheep from low level military aircraft. In an effort to minimize potentially negative impacts, the USAF has implemented mitigation measures at a known lambing area, Cirque Lake (Fig. 2.1). Mitigation measures applied to this area occur from 10 May – 15 June. During this time, military aircraft are restricted to flying 5,000 feet (1,500 m) above ground level in the Cirque Lake mitigation area. At other times of the year, and in the surrounding area, military aircraft may fly as low as 100 feet (30 m) above ground level (Department of the Air Force 1995).

The fundamental concern regarding aircraft impacts on wildlife species is the potential for long-term negative effects on populations due to human disturbance. Population decline can be brought about by a decline in survivorship, a decline in fecundity or changes in immigration and emigration. Studies investigating aircraft impacts on wild sheep populations have focused on short-term effects (Krausman and Hervert 1983, Lenarz 1974, MacArthur et al. 1979, Stockwell et al. 1991, Krausman et al. 1993, Bleich et al. 1994, Weisenberger et al. 1996, Krausman et al. 1998). While insightful, these investigations do not provide a direct measure of the demographic processes that control population levels. Therefore, inferences of long-term effects based on short-term responses are strengthened in those instances in which long-term effects can also be assessed.

In this study, we investigated long-term effects of military jet overflights on 6 parameters. We investigated body weights, age, pregnancy rates, the number of lambs, the number of yearlings, and survival rates of ewes in 2 Dall's sheep populations exposed to military jet overflights. One population is mitigated for potential negative impacts (Cirque Lake) and the second (West Point/Puzzle Gulch) is not. Because there were no sheep populations within the general vicinity that were not exposed to military overflight activity, our study is restricted to comparisons of the mitigated area versus a non-mitigated area. We predicted Dall's sheep ewes at the non-mitigated location would be lighter, would have lower reproductive success (pregnancy rates, lamb to ewe ratio and yearling to ewe ratio), and lower survival than would sheep in the mitigated area.

STUDY AREA

Dall's sheep were captured, and indices of productivity and survivorship, were gathered at 2 study locations in eastern interior Alaska in the Yukon-Tanana Uplands (Fig. 2.1). One site is mitigated for potential impacts of low level military jets (Cirque Lake) and the second site is not (West Point/Puzzle Gulch). The 2 study sites occur approximately 35 km apart and can be typified as rugged alpine landscapes separated by wooded areas. The climate and vegetation typical of the study site has previously been reported (Chapter 1). Dall's sheep density were 0.10 sheep per km^2 and 0.19 sheep per km^2 at Cirque Lake and West Point/Puzzle Gulch, respectively during the final year of this study (2002) and the sheep population at the 2 study sites was relatively stable throughout the course of this study (chapter 1). Potential predators known to exist in the area include black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), wolves (*Canis lupus*), wolverines (*Gulo gulo*), lynx (*Lynx canadensis*) and golden eagles (*Aquila chrysaetos*)(Appendix C).

METHODS

Sheep captures were accomplished with a hand-held netgun using a helicopter (Robinson R-44) as a platform. Ten sheep were radiocollared at each study site in March of 1999, 2000 and 2002 (20 radiocollared Dall's sheep per year). During March 2001, 10 sheep were radiocollared at West Point/Puzzle Gulch but due to problems locating sheep, only 7 were captured at Cirque Lake. Out of 84 total sheep that were netgunned during this project, one died during capture. This animal stopped breathing and could not be revived. A necropsy performed on this animal did not reveal the cause of death (C. Rosa, DVM, University of Alaska Fairbanks, personal communication). A second sheep died 6 days after capture from an unknown predator. All remaining radiocollared sheep survived at least a minimum of 27 days following capture. Capture methodology was within the guidelines established by the American Society of Mammalogists (Animal Care and Use Committee 1998).

Physical measurements recorded for captured sheep were metatarsal length, chest girth, body length, neck circumference, horn length, horn circumference, and body weight (Appendix B). Blood samples (30 cc) were collected from captured animals and assayed for progesterone concentrations by the Institute of Arctic Biology, University of Alaska Fairbanks to determine pregnancy rates of captured sheep. Sheep with blood levels of >2ng of progesterone/ml of serum were classified as pregnant (Ramsay and Sadleir 1979; Brundige et al. 1988). A subjective determination of relative body condition was assigned to each animal (Gerhart et al. 1996). Subjective scores were assigned based on a scale from 1 to 5 (1 = emaciated, 5 = obese). Sheep age was estimated by counting horn annuli (Geist 1971) and by assessing incisor wear. Age estimated by counting horn annuli has a tendency to underestimate sheep ages in comparison to canine tooth cementum analysis in older ewes (Kleckner et al. 2002) and for this reason, we consider ages of sheep listed in this report to be conservative.

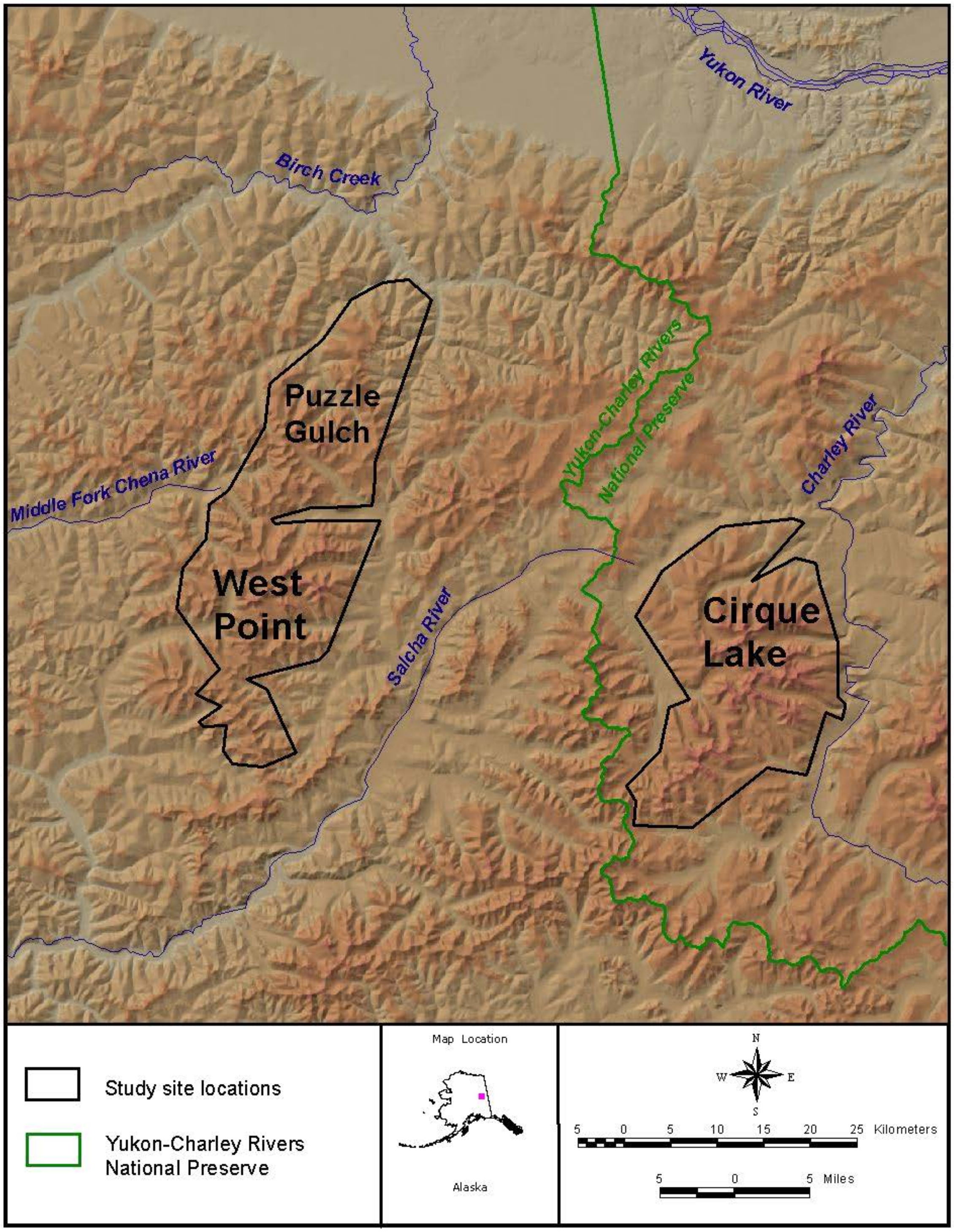


Figure 2.1. Location of study sites in interior Alaska. One study site is mitigated (Cirque Lake) for potential impacts of low-level military jet overflights, and the other (West Point/Puzzle Gulch) is not. Ten Dall's sheep were captured in March of each year from 1999 – 2002 at each study site with the exception of Cirque Lake in 2001 when 7 sheep were captured.

Each year during this study (1999-2002), aerial surveys were conducted to count sheep within study units in early to mid-July (Appendix A; Chapter 1). Sheep were classified during this survey as rams (all animals with >1/4 curl horn size), ewe-like (rams $\leq$ 1/4 curl and all adult ewes), lambs, and yearlings (the yearling category contained primarily ewes as yearling rams would likely be classified as “ewe-like”). In addition to the total number of sheep observed in each of the study units (Chapter 1), other measures of survival and productivity can be derived from this data. The number of lambs:100 ewe like sheep provides an indication of productivity. As this value is estimated in mid-summer, it is not a measure of lambing rates but is a combination of lambing rates and 1-2 month lamb survival. The yearling:100 females value provides an upper index for the number of ewes from a specific cohort that can be recruited into the breeding population.

Dall’s sheep mortalities were initially investigated from the fixed-wing aircraft. At the earliest opportunity, sites were visited on the ground but this often occurred long after the animal had died. Indication of cause of death was recorded when possible. We did not directly observed any predation but assumed sheep were depredated if there were signs of a struggle or if there was an abundance of bright red blood in the area. We assumed blood from an animal that had died while still intact would be dark and coagulated and, in the wintertime, frozen, thereby limiting dispersal.

Sheep survival was investigated using the Kaplan-Meier procedure extended to allow staggered entry of radiocollared sheep during each year of this study, and allowing failed radiocollars to be right censored from the data set (i.e., failed collars were excluded from analysis after disappearance; Pollock et al. 1989).

DATA ANALYSIS

A multivariate analysis of variance (MANOVA) was used to compare body weights and age (dependent variables) of sheep at the 2 study sites and between years (independent variables). We used two-tailed *t*-tests to examine differences in pregnancy rates, ewe survival rates (from mid-March – mid-November), lamb:100 ewes ratios, and yearling:100 ewe ratios between the 2 study sites. Because rates and ratios vary between 0 and 1 and, therefore, typically have a binomial rather than a normal distribution (Zar 1996), we arcsine transformed all rate and ratio data prior to analysis to avoid problems with data distribution. Body weight and age of pregnant versus non-pregnant ewes, and body weights and age of sheep that lived and died in the months following capture were also compared using two-tailed *t*-tests. The relationship between body weight and pregnancy status, and body weight and survival was described with univariate logistic regression. We tested for differences in Kaplan-Meier survival functions using a Chi-square test (Pollack et al. 1989). Statistical tests were considered significant if $P \leq 0.05$.

RESULTS

Mean ($\pm$SD) age of captured sheep was similar between the 2 study sites (6.7 [$\pm$1.59] and 6.9 [$\pm$1.84] years for West Point and Cirque Lake respectively; Fig. 2.2). Age of captured sheep varied between 3 years of age (Cirque Lake and West Point) and 11 years of age (Cirque Lake)(Fig. 2.2). There was a slight tendency for age of capture sheep to

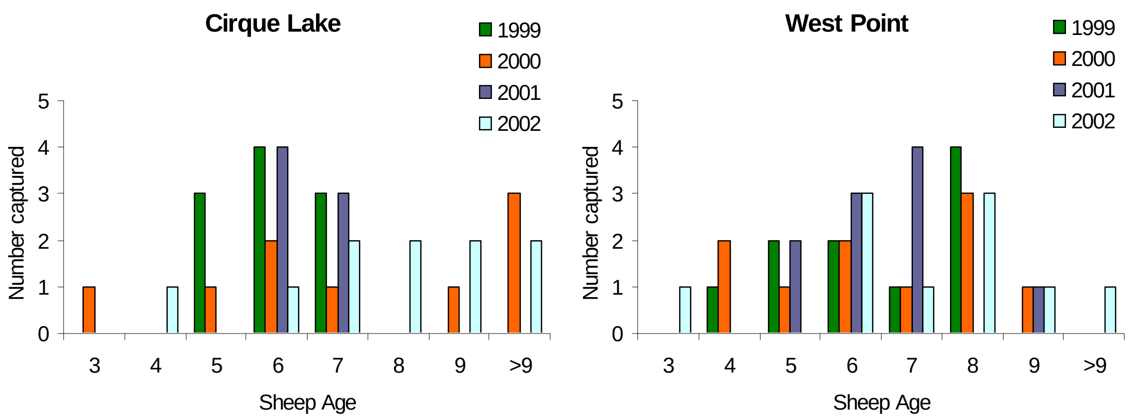


Figure 2.2. Age distribution of Dall's sheep captured in March of 1999 (*n* = 20), 2000 (*n* = 19), 2001 (*n* = 17), and 2002 (*n* = 20) in interior Alaska at a study site mitigated for military aircraft overflights (Cirque Lake) and at a non-mitigated site (West Point).

increase as the study progressed. Annual mean body weights of captured Dall's sheep have been consistently greater at West Point in comparison to Cirque Lake (Fig 2.3). Differences in weights between the 2 study areas were greatest when the study was initiated and approached parity during the final year of the study.

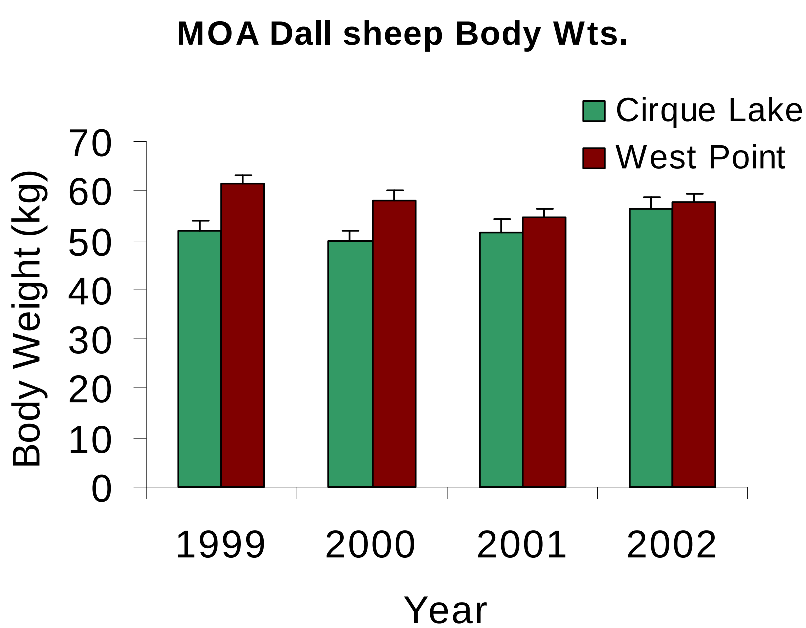


Figure 2.3. Body weights (mean $\pm$ SE) of Dall's sheep captured in March of 1999 (*n* = 20), 2000 (*n* = 18), 2001 (*n* = 12), and 2002 (*n* = 17) in the Yukon-Tanana Uplands of interior Alaska at a study site mitigated for military aircraft overflights (Cirque Lake) and at a non-mitigated site (West Point).

Examination of multivariate results indicates the dependent variables (sheep age and body weight) were effected by study site selection ($F_{2, 62}$ = 6.699, Pillai's trace P = 0.002) and not by sampling year ($F_{6, 126}$ = 1.929, Pillai's trace P = 0.081). The interaction between sampling year and study site selection was also significant ($F_{6, 126}$ = 6.699, Pillai's trace P = 0.045). Univariate results as a follow up to the mutivariate approach indicate body weight differed significantly between the 2 study sites ($F_{1, 63}$ = 9.254, P = 0.003) and age did not ($F_{1, 63}$ = 0.289, P = 0.593). Univariate results also indicated that body weight was significant in the area by year interaction ($F_{3, 63}$ = 3.608, P = 0.018) and age was not ($F_{3, 63}$ = 0.653, P = 0.584).

Annual pregnancy rates tended to be higher at West Point in comparison to Cirque Lake. For both areas, pregnancy rates were lower in 2000 and 2001 in comparison to 1999 and 2002 (Table 2.1). Differences in pregnancy rates at the 2 study sites were not found to be significant (t = 1.030, df = 4.1, P = 0.360).

Table 2.1. Dall's sheep pregnancy in interior Alaska at a study site mitigated for the impacts of military aircraft overflights (Cirque Lake) and at a non-mitigated site (West Point) during March of 1999, 2000, 2001 and 2002.

	Study Site			
	Cirque Lake		West Point	
Year	Sample size (*n*)	# Pregnant	Sample size (*n*)	# Pregnant
1999	10	7	10	10
2000	9	4	10	6
2001	7	4	9	4
2002	8	7	10	10
Total	34	22	39	30

A *t*-test indicated mean age ($\pm$SE) did not differ between ewes that were pregnant and those that were not (6.8 [$\pm$0.23] years and 6.4[$\pm$0.35] years, respectively; t = 1.071, df = 70, P = 0.288). Mean ($\pm$SE) body weights of pregnant Dall's sheep (58 kg [$\pm$0.8] kg) were greater than non-pregnant sheep (51 kg [$\pm$0.23kg] kg) and this difference was significant (t = 4.607, df = 66, P <0.001). A logistic regression model indicated that sheep needed to weigh at least 50 kg before they had a $\geq$0.50 probability of being pregnant (Fig. 2.4). The model correctly predicted the pregnancy status (preganant or not) of 77% of the sampled sheep.

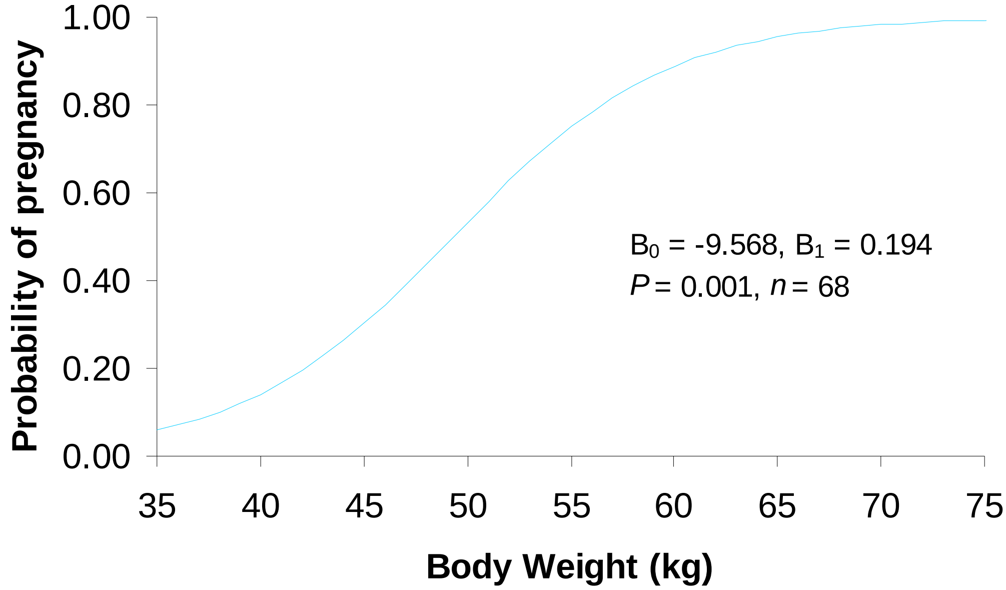


Figure 2.4. The logistic relationship between the probability of pregnancy and body weight (kg) for adult Dall's sheep ewes in the Yukon-Tanana uplands, Alaska. Coefficients presented are for the logistic equation of the form: $Pr(X) = e^{g(x)}/(1 + e^{g(x)})$, where $g(x) = \beta_0 + \beta_1 X_1$, and Pr(X) is the probability of pregnancy at a particular X_1.

The number of lambs:100 ewes observed during July surveys varied between 57 (Cirque Lake, 1999) and 25 (Cirque Lake, 2001). No trend was apparent in lamb:100 ewes when comparing study locations or when comparing years (Fig. 2.5). In contrast, the yearling:100 ewes ratio tended to decline from 1999 to 2002 and Cirque Lake had higher yearling:100 ewes ratios than did West Point/Puzzle Gulch (Fig. 2.5). The number of yearlings:100 ewes varied between 45 (Cirque Lake, 1999) and 13 (West Point/Puzzle Gulch, 2001). Statistically, no difference between study sites was found for lambs:100 ewes ($t = 0.043$, df = 4, $P = 0.967$) or for the number of yearlings:100 ewes($t = 2.258$, df = 4, $P = 0.087$). We were only able to evaluate the change in the number of lambs: 100 ewes to yearling: 100 ewes in one year (2002). At Cirque Lake during 2001, 25 lambs: 100 ewes resulted in 25 yearlings:100 ewes in 2002, a 0% decline. At West Point, 33 lambs: 100 ewes in 2001 resulted in 15 yearlings:100 ewes in 2002, a decline of more than 50%.

Out of 77 sheep that were collared over 4 years in the 2 study units, 14 died (18%) while radiocollared (Table 2.2). The number of sheep mortalities was comparable between the 2 study sites (8 at Cirque Lake and 6 at West Point). Yearly mortalities were the same during 1999 and 2001, slightly higher during 2000 and nonexistent in 2002 (Fig 2.6). It should be noted however, that 3 of the mortalities at the West Point study site may have been the result of 1 predation event (by wolves) as the mortalities were detected at the same time and appeared to be of similar age. Upon investigation, the remains of 6 sheep (3 with radiocollars) were detected within a 1 km radius.

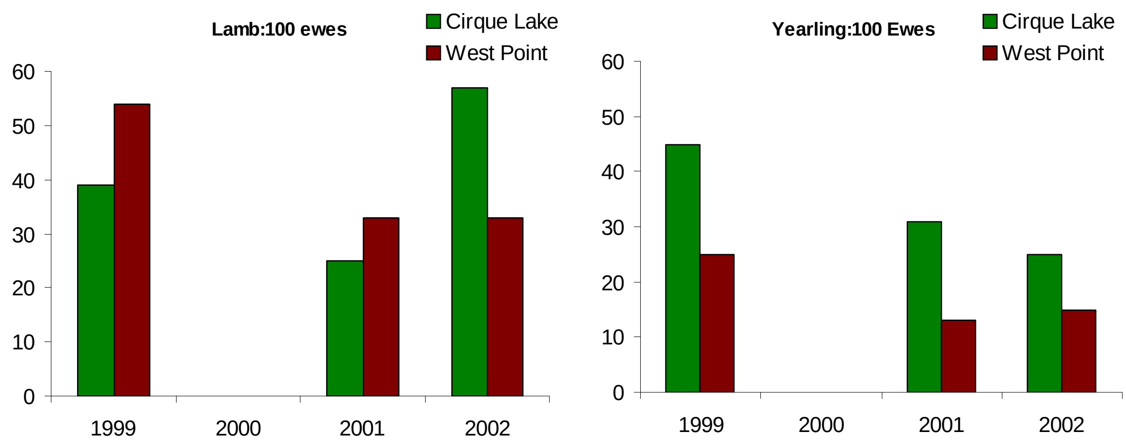


Figure 2.5. Lambs:100 ewes and yearlings:100 ewes observed in July in interior Alaska during an aerial survey. Sheep were surveyed at a study site mitigated for military aircraft overflights (Cirque Lake) and at a non-mitigated site (West Point/Puzzle Gulch).

Table 2.2. Cause of death for Dall's sheep captured in March of 1999 (*n* = 20), 2000 (*n* = 20), 2001 (*n* = 17), and 2002 (*n* = 20) in the Yukon-Tanana Uplands of interior Alaska at a study site mitigated for military aircraft overflights (Cirque Lake) and at a non-mitigated site (West Point).

Location	Year	**Age of sheep**	**Cause of Death**
Cirque Lake	1999	6	Unknown; consumed by bear
		7	Capture/radiocollar removal
	2000	8	Unknown predator; partially consumed by wolverine
		9	Unknown predator
		3	Unknown predator
		10	Unknown
		10	Unknown
	2001	7	Unknown; partially consumed by wolverine
	2002		NA
West Point	1999	8	Unknown predator
		8	Unknown; consumed by bear
	2000	9	Unknown
	2001	4	Wolf predation
		7	Wolf predation
		7	Wolf predation
	2002		NA

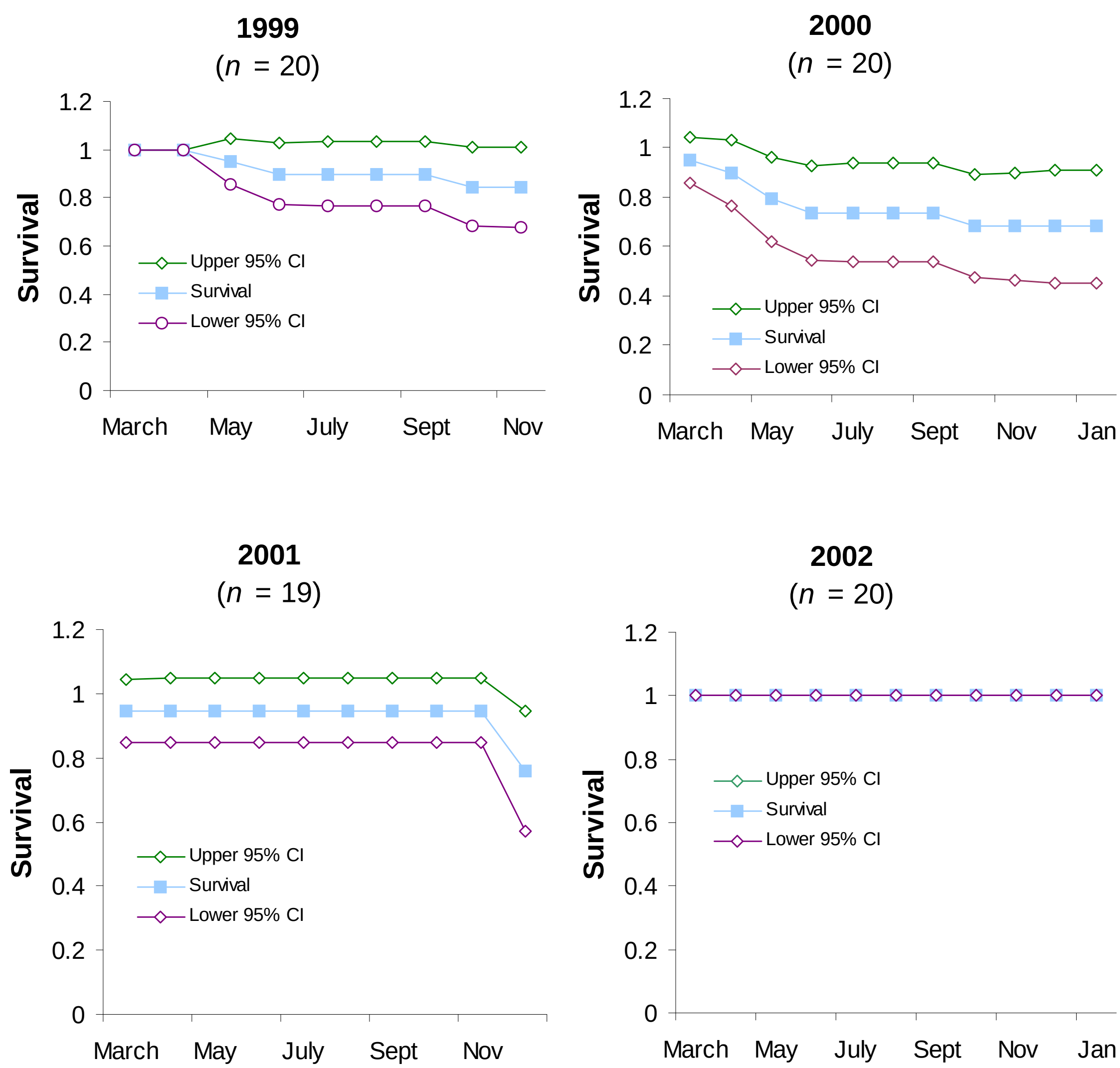


Figure 2.6. The Kaplan-Meier survival probability function for Dall's sheep radiocollared in the Yukon-Tanana Uplands, interior Alaska. Data presented is combined from 2 study sites and is monthly survival by year.

Survival from mid March – mid January was comparable at Cirque Lake and West Point (0.80 and 0.82, respectively) during the 4 years of this study (Chi-square = 0.463, P = 0.50). The pattern of survival we observed indicate most mortalities occur from late winter through lambing (mid March – mid June; Fig. 2.7). The sharp decline in survival at West Point between mid-November and December was due to the probable wolf predation event previously described.

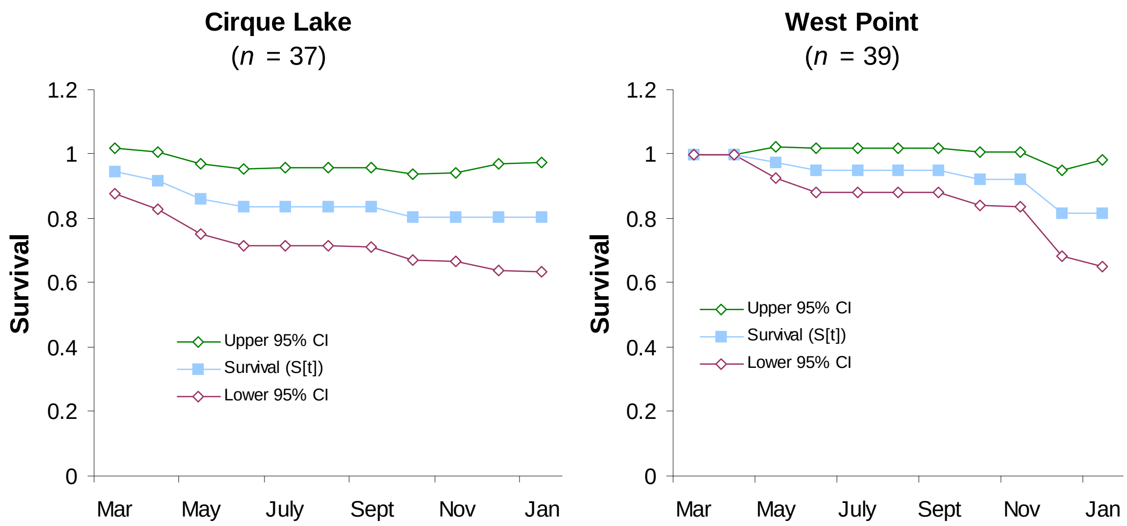


Figure 2.7. The Kaplan-Meier survival probability function for Dall's sheep radiocollared in the Yukon-Tanana uplands, interior Alaska at 2 study sites. One site (Cirque Lake) is mitigated for the potential negative impacts of military jet overflights and the second (West Point) is not. Data presented is for monthly survivorship and was collected over 4 years (1999-2002).

Mean (±SE) age of radiocollared sheep that died (7.2[±0.55]) during this study did not differ significantly (t=0.844, df = 74, P= 0.402) from those that survived (6.7[±0.21]) Dall's sheep survival was significantly effected by body weight (t=2.015, df = 70, P= 0.048). Mean (±SE) weights of radiocollared Dall's sheep that died during this study were 53 kg (±2.1) and those that survived were 57 kg (±0.8). A logistic regression model supported the conclusion that heavier sheep tended to have a higher probability of survival (Fig. 2.8). The model correctly predicted the survival (dead or alive) of 82% of the sampled sheep.

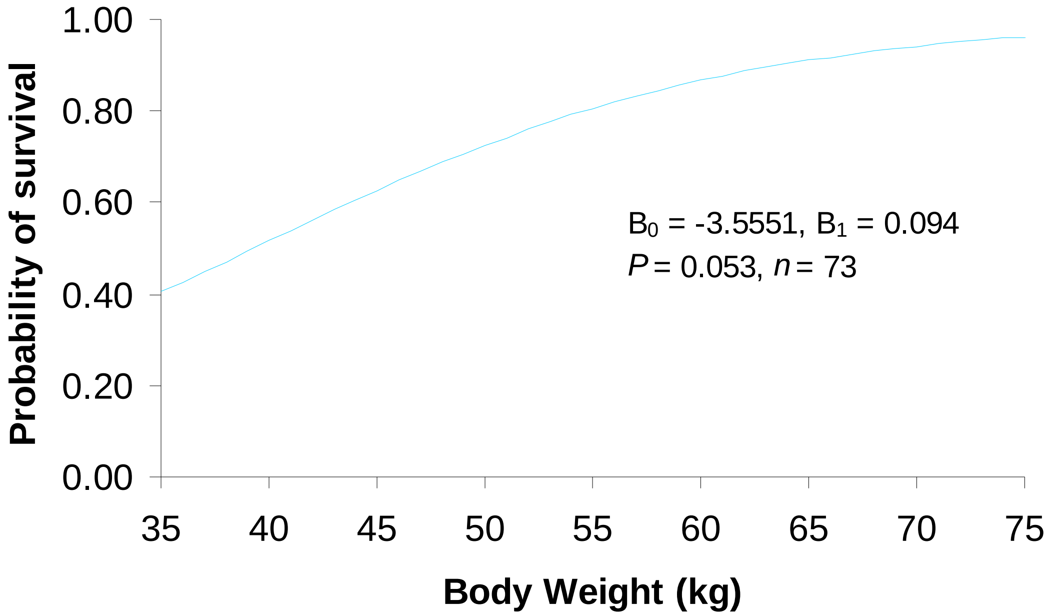


Figure 2.8. The logistic relationship between the probability of survival and body weight (kg) for adult Dall's sheep ewes radiocollared in the Yukon-Tanana uplands, Alaska. Coefficients presented are for the logistic equation of the form: $Pr(X) = e^{g(x)}/(1 + e^{g(x)})$, where $g(x) = \beta_0 + \beta_1 X_1$, and Pr(X) is the probability of survival at a particular X_1.

DISCUSSION

Our predictions that Dall's sheep ewes at the non-mitigated location would be lighter, would have lower reproductive success (pregnancy rates, lamb to ewe ratio and yearling to ewe ratio), and lower survival than would sheep in the mitigated area was generally not supported (Table 2.3). Indeed, the only parameter that was found to be statistically different between the 2 study sites was body weight, and ewes in the non-mitigated (West Point/Puzzle Gulch) site weighed more than ewes at the mitigated site (Cirque Lake). The trend in pregnancy rates also leads to the conclusion that conditions were better for Dall's sheep at West Point/Puzzle Gulch than at Cirque Lake. The only result that contradicts this and supports our initial predictions was the higher yearling: 100 ewe ratio at Cirque Lake in comparison to West Point and this result was not significant. It appears likely, therefore, that factors other than the presence or absence of mitigation measures are responsible for observed Dall's sheep productivity and survivorship at these 2 study sites during this study.

Not surprisingly, many of these productivity parameters appear to be related (Table 2.3). In those instances in which ewes were heavier, pregnancy rates were higher and lambing rates and survival tended to be better. The reverse was true when ewes were lighter. The effect of body weight on pregnancy rates is not surprising as autumn body weight has been shown to correlate to pregnancy rates in other northern ungulates (Albon et al. 1986, Cameron et al. 1993, White et al. 1997). It is also logical that lambs: 100 ewes would be related to pregnancy rates.

Table 2.3. Summary of measures of productivity over a 4 year study of Dall's sheep in the Yukon-Tanana Uplands of interior Alaska. Productivity parameters were collected at at 2 study sites. One site was mitigated for the potential impacts of low level military overlfights (Cirque Lake) and second site was not. Data is summarized by year and by study site. The highest measure of a particular parameter is highlighted in blue.

	By Year				By Area	
	1999	2000	2001	2002	Cirque Lake	West Point
Body Weight*	57	54	53	57	52	58
Pregnancy Rates+	85	50	50	95	64	77
Lambs: 100 ewes	46		29	45	40	40
Yearlings: 100 ewes	35		22	20	33	17
Survival	84	68	95	100	80	82

* Body Weight in kg.
+ Pregnancy rates as percentage tested.

Of the results presented in this paper, likely the most difficult to interpret is the mean age of captured ewe. Because of small sample sizes in each age category, a few individuals could make substantial changes in the distribution of ages of captured sheep. Two observations are possible however. The mean age of captured sheep at the 2 study sites (6.7 and 6.9 at West Point and Cirque Lake, respectively) is near the median for all sheep captured (7) indicating a relatively even distribution between the oldest and youngest sheep we captured (3 and 11 years, respectively). Survival, therefore, appears to have been relatively constant for this age bracket of ewes. This pattern is consistent with life-expectancy tables that have been published for this species (Murphy and Whitten 1976, Hoefs and Cowan 1979). The second observation is the lack of younger sheep in the sample. Because we specifically selected mature adult ewes in our capture efforts and this selection was based on comparative body size, we may have selected against any ewe younger than 4 years with 2 exceptions. Therefore, sheep in this population may be reaching adult size when they are 4 years old. Because smaller sheep are less likely to be pregnant, the successful breeding of 2 and 3 year old ewes seems doubtful.

Mean (±SE) body weights we recorded during this study (55.9[±0.77]) were high in comparison to that reported in the literature. Mean body weights for adult ewes in the spring during a study conducted in the Alaska Range was 47.2 kg (Heimer 1972). For Dall's sheep in the Yukon Territory in the late winter, mean body weights were 48.8 kg (Bunnell and Olsen 1976). In a study in the Central Brooks Range, mean body weights were 50.0 (±2.09) kg (Lawler 2004). Therefore, in comparison to populations of Dall's sheep that were not overlain by MOA airspace , body weights in both study sites the Yukon-Tanana Uplands (mitigated and non-mitigated) do not appear to be suffering from exposure to low-level military jet aircraft.

Our results for pregnancy rates, lamb:100 ewe ratios, and yearlings:100 ewe ratio all showed considerable variation. This sort of variability appears to be the rule in Dall's sheep populations (Nichols and Bunnel 1999). Pregnancy rates and lambing rates would both depend on a ewes nutritional status which in turn is effected by the current forage available to the ewe as well as the forage available during the previous winter and summer. Similarly, yearling survival is dependent on the current forage available to them, their nutritional plane during the previous winter and summer and their vulnerability to predation pressures. Forage quantity and quality has been proposed as the ultimate factor limiting growth and populations of Dall's sheep (Nichols and Bunnel 1999). Forage quantity and quality appear to be simlar at the 2 study sites in this study (Appendix D). Winter weather, and particularly snow cover, is extremely important as it can control habitat availability. Both Murphy (1974) in Denali National Park Alaska, and Nichols (1978) on the Kenai Peninsula of Alaska found lambing rates in the spring to be inversely related to snow depth the previous winter. In soft-snow, 30 cm has been proposed as the limit under which Dall's sheep can effectively forage (Hoefs and Cowan 1979, Nichols 1988). Therefore, some of the variation we observe could be related to factors such as weather.

Relative to other Dall's sheep populations, lamb:100 ewe ratios, and yearling:100 ewe ratios we observed in the Yukon-Tanana Uplands were comparable. Nichols (1978) presented statistics from numerous surveys of Alaska Dall's sheep populations in the Brooks Range, Central Alaska, and the Kenai Mountains and found a mean (±SE) lamb: 100 ewe ratio of 37 (±2.1) (n =57). The mean (±SE) lamb:100 ewe ratio we observed during this 4 year study was 40 (±5.2) (n = 6). Statistics for mean (±SE) yearling:100 ewes ratios presented by Nichols (1978) were 21 (±0.02) (n = 59) ewes. We observed mean yearling:100 ewe ratios of 25.7 (±4.75) (n = 6). The over winter survival of lambs during their first winter in this study is difficult to assess as we only have 1 year in which to make this comparison. In this 1 year we saw 100% survival at one of the study sites (Cirque Lake) and a 45% survival rate at the second site (West Point). Therefore, in comparison to populations of Dall's sheep in areas ouside of the MOA structure, lambing rates, yearlings rates and first year survival of lambs are all good and do not appear to have been compromised by military flying currently occurring in the Interior Alaska MOAs.

Survival of adult ewes in this study was comparable to that observed in other populations. Hoefs and Cowan (1979) reported an average annual mortality rate of 20% for ewes in Kluane National Park, Canada. Simmons et al. (1984) estimated an average annual mortality of 15% for adult ewes in both the Mackenzie Mountains of Canada and in Denali National Park. We found mortality rates at the 2 study sites to be 20% and 18%

(Cirque Lake and West Point, respectively). Based on the observation that these populations appear to have been stable over the last 4 years (Chapter 1), these mortality rates appear sustainable and are not extraordinary in comparison to other populations.

Weisenberger et al. (1996) and Krausman et al. (1998) investigated heart rate and behavior of bighorn sheep (*Ovis canadensis nelsoni*) and found short-term effects on these variables from simulated noise of low-level jet overflights or from overflights by F-16 jets. Within a short time however, heart rates returned to pre-disturbance levels (generally <3 minutes) as did behavior (<5 minutes) and these authors concluded that mountain sheep reactions to F-16 overflights were minor. Responses to military jet aircraft or from simulated military jet aircraft appeared to be short-lived in their study and response times declined with repeated exposure (Weisenberger et al. 1996) suggesting sheep habituate to aircraft overflights. In regard to long-term effects, Weisenberger et al. (1996) did not find long-term effects on heart rate in bighorn sheep exposed to simulated noise of low-level jets. Krausman et al. (1998) present antidotal information that low-level military jet aircraft did not adversely effect reproduction in a group of bighorn sheep in Nevada. These animals were kept in a large enclosure over a 2 year period and were subjected to military overflights during the second year. In the 1st year of their study, 8 ewes were observed with 6 lambs. In the following year, when the sheep were exposed to overflights, 8 ewes were observed with 7 lambs. In both years of their study, sheep within the enclosure had higher pregnancy rates than did free ranging sheep in nearby populations who were rarely exposed to overflight events (1/month).

In conclusion, documenting long-term effects of aircraft overflights on wildlife species, such as effects on reproduction or survival, is difficult (National Park Service 1994). Previous workers examining long-term effects of military overflights on other northern ungulates have reached varying conclusions regarding the effects of military overflights on wildlife species from no effect on population dynamics in caribou (*Rangifer tarandus*; Davis et al. 1985), changes in activity budgets in caribou (with the potential to have long term effects; Murphy et al. 1993) to increased calf mortality in woodland caribou (*Rangifer tarandus caribou*; Harrington and Veitch 1992). In this study, we looked at long-term effects of military overflight on Dall’s sheep body weights, age, pregnancy rates, the number of lambs, the number of yearlings, and survival rates of Dall’s sheep ewes in an area mitigated for the potentially negative impacts of military overflights, and an area that isn’t mitigated and is heavily overflown by military aircraft. The preponderance of evidence suggests that the current mitigation measure is not providing any measurable long term advantage to sheep at Cirque Lake (mitigated) in comparison to West Point (not mitigated). However, we could find no indication that current levels of military overflights are causing long-term harm to sheep in the Yukon-Tanana Uplands as the population parameters we measured are comparable to sheep populations that are not exposed to low-level military aircraft.

SUMMARY

We investigated body weights, age, pregnancy rates, the number of lambs, the number of yearlings, and survival rates of ewes in 2 Dall’s sheep populations exposed to military jet overflights. One population is mitigated for potential negative impacts (Cirque Lake) and the second (West Point/Puzzle Gulch) is not. Body weight was the only parameter out of the six examined that differed significantly between West Point and Cirque Lake. Sheep at West Point were heavier than those at Cirque Lake. Based on these six measures of individual and population health, the current mitigation measure is not providing any measurable long term advantage to sheep at the mitigated site in comparison to a non-mitigated site.

CHAPTER 3: Dall's sheep behavior in relation to military overflights in interior Alaska in mitigated and non-mitigated military overflight areas

INTRODUCTION

Wild sheep have been shown to have varying short term or instantaneous behavioral reactions to aircraft activity (MacArthur et al. 1982; Krausman and Hervert 1983; Stockwell et al. 1991; Krausman et al. 1993, 1998; Weisenberger et al. 1996) leading to concerns of negative impacts on Dall's sheep (*Ovis dalli*) from low level military aircraft in Interior Alaska Military Operations Areas. Wildlife behavior has been used as a means for evaluating anthropogenic disturbance with the premise that changes in individual behavior may have long–term population level consequences (Klein 1973, Harrington and Veitch 1991, Frid and Dill 2002). Various metrics of animal behavior and activity have been used to evaluate the potential effects of overflights on wildlife species. Three such measures are the proportion of time animals spend active, feeding efficiency, and proportion of time (animals) are engaged in specified behavior categories (i.e., activity budgets).

One of the most basic measures of animal activity is the proportion of time animals spend active. Harrington and Veitch (1991) found an increase in daily activity in caribou (*Rangifer tarandus*) related to military overflights in 1 field season out of 3. Murphy et al. (1993) and Maier et al. (1998) found increased activity in caribou overflown by military jets in comparison to caribou that were not subjected to overflight activity in 2 out of 3 sampling periods during 1991. Heart rate of wild bighorn sheep (*Ovis canadensis*; MacArthur et al. 1979) and energy expenditure in wild ungulates in general increases as animals go from a position of inactivity (bedding) to active (standing, feeding walking and running) (Fancy and White 1985). Therefore, in the instances cited above, military overflights caused an increase in energy expenditure in caribou but cumulative seasonal or annual changes in energy expenditure have not been estimated.

A reduction in feeding efficiency has also been used as an indication of disturbance (Berger et al. 1983, King and Workman 1986, Stockwell et al. 1991). Foraging efficiency can be defined as an index of time spent feeding relative to time spent scanning. Stockwell et al. (1991) found that in winter with intense helicopter activity, bighorn sheep foraged less efficiently in the presence of helicopters than in the absence of helicopters.

Wildlife activity budgets are useful for evaluating potential disturbance because trade-offs in behavior can be evaluated and a relative degree of disturbance can be assigned based on a specific change in behavior. MacArthur et al. (1982) found that bighorn sheep exposed to helicopter overflights at 90-250 m above ground level, responded by running. Murphy et al. (1993) found that caribou spent significantly less time lying during post-calving and insect season if they had been overflown in the last 15 minutes in comparison to a group that had not been overflown. Frid (1998) reported that 75% of Dall's sheep groups that he observed responded to low-level helicopter flights by having at least some members of the group walk or run in response to the overflight. Krausman et al. (1998) reported limited changes in proportion of time standing, walking and foraging in bighorn sheep following military overflights and concluded that there were no measurable differences in behavior between overflown and non-overflown sheep. Similarly, Krausman et al. (2001) did not, in general, find significant differences in behavior patterns of adult pronghorn (*Antilocapra americana*) with and without military overflight acitivity.

We examined behavior of Dall's sheep in relation to military overflights by evaluating the proportion of Dall's sheep that were active, Dall's sheep feeding efficiency, and Dall's sheep activity budgets. Military overflight activity was quantified as the number of military jets observed during an observation bout, the time relative to the overflight event (before, during or after), and flight and sound characteristics of the overflight event. We tested the null hypothesis that the proportion of Dall's sheep active, feeding efficiency and activity budgets would not be associated with military overflights. Because group size (Frid 2003), presence of lambs, distance to steep rocky terrain (Frid 2003), and time of year (Stockwell et al. 1991, Bleich et al. 1994) could all potentially affect behavioral responses of mountain sheep, we included these variables in our analysis. To guard against differences in study site location and differences in seasonal progression across year, we also included these variables in our analysis.

STUDY AREA

Observations of Dall's sheep were made at 2 study sites in eastern interior Alaska in the Yukon-Tanana Uplands (Fig. 3.1). One site was mitigated for potential impacts of low level military jets (Cirque Lake) and the second site was not (West Point). The 2 study sites were approximately 35 km apart and have been previously described (Chapter 1).

Mitigation measures at Cirque Lake are in effect 10 May – 15 June. During this time frame, military aircraft are to avoid the Cirque Lake lambing area by maintaining a 5,000 foot (1,500 m) floor in a 7-nautical mile (13 km) radius circle centered at 64º48'00"N, 143º45'00"W. At other times of the year, and in the surrounding area, military aircraft may fly as low as 100 feet (30 m) above ground level (AGL; Department of the Air Force 1995). Sheep at both study sites may be exposed to military aircraft during both routine flying days as well as during Major Flying Exercises. The most prominent Major Flying Exercises are termed Cope Thunders (Department of the Air Force 1995).

The Final Environmental Impact Statement, Alaska Military Operations Areas (1995) indicates that in interior Alaska, routine military aircraft training exercises typically occur between 0800h and 2200h, Monday through Friday. Cope Thunders typically occur Monday through Friday, 0800h through 1800h but are most concentrated from 1000h through 1200h, and 1500h through 1700h. A typical Cope Thunder is 10 days long. Between 55 and 110 aircraft a day can be involved in a Cope Thunder, with each aircraft flying up to 2 sorties (a sortie is a single aircraft take-off, flight, and landing) per day for a total of up to 200 sorties per day (Department of the Air Force 1995). Cope Thunders can be distinguished from routine flying by a 50% or greater increase in the daily flying activity rate relative to routine flying days or an increase of 50 aircraft operations per day (Department of the Air Force, 1995).

METHODS

Overflight Activity

Two initial assumptions of this study were that: 1) Dall's sheep at the West Point study site were exposed to greater levels of military jet overflights than were sheep at the Cirque Lake study site; and 2) military overflight activity at both study sites was greater during major flying excercises (Cope Thunders) than on routine flying days. Overflight activity at Cirque Lake was also expected to vary in relation to the mitigation measure. These assumptions were investigated by examining the number of overflights observed by field crews while observing sheep behavior and by quantifying sound levels during these overflights.

Field crews observed Dall's sheep behavior, observed overflight activity and collected information on sound levels during military overflights during 4 field sessions per year in 2000 and 2001. All behavioral observations of Dall's sheep occurred in Yukon MOA 1 with the exception of 1 observation period (21 February – 5 March at the West Point study site). We attempted to distribute our field efforts between those periods with the most intense overflight activity (Cope Thunders) and those periods with reduced overflight intensity (routine flying). Data gathered included the number of aircraft observed while in the field and the number of overflight events that occurred while observing sheep. We collected data on overflights at all altitudes and proximities that we could detect. Military aircraft rarely travel alone. Because of logistical constrains in regards to sound meters and data recording, data collection focused on the nearest aircraft at any given time. We considered a pass by an aircraft or a group of aircraft to be an overflight event when either the sound associated with the overflight reached a peak or the proximity of aircraft to the observed sheep reached a minimum followed by either a decline in sound level or a decrease in proximity. Therefore, multiple passes by a single aircraft resulted in multiple overflight events. Observed overflights were categorized by type as military jet, military prop., small non-military (single engine prop.), helicopter, or other (civilian multi-engine, non-military jet or unknown). Proximity of overflights were categorized as close, moderate, or far using known elevations of mountains in the study area. An overflight was considered to be close if the observer considered the aircraft overflight to be below 1500 m AGL (5,000 feet) and to be within 1.6 km (1 mile) horizontal distance of the Dall's sheep under observation. Overflights were considered moderate if below 1500 m AGL and within horizontal distances of 1.6-3.2 km (1-2 miles). Overflights judged to be greater than 1500 m AGL and greater than 3.2 km horizontal distant were considered far. We therefore, investigated Dall's sheep reactions to aircraft activity that we assumed to be representative of that typically occurring in the Yukon MOA 1. Analyses of Dall's sheep behavior presented in this report focus on reactions relative to military jets. Sample sizes of overflights by military prop aircraft and helicopters were too small to allow analysis. Statistical analysis of overflights by small single engine civilian aircraft is presented in Appendix E.

Once crews were in place to observe sheep, a sound level meter (Larson Davis Model 812 sound level meter, Model 2560 microphone, and Model PRM826B preamp) was positioned at least 200 m from each crew. Sound meters were programmed to record A-weighted 2 minute average sound levels (L_{eq}) and peak sound levels in 2 minute blocks. A-weighting is a filter that adjusts sound level frequencies similarly to the human ear when exposed to low levels of sound and is most often used to evaluate environmental sounds (Larson·Davis 1997). For statistical analysis, we used the mean L_{eq} in 2 minute time blocks as L_{eq} has been suggested as an appropriate metric of sound measurements for wildlife studies (Krausman et al. 2001). Sound data presented in this report were the sound levels at the observation sites during the overflights, but do not represent exact sound levels or peaks that Dall's sheep experienced during the overflights because the monitoring equipment was not directly associated with individual sheep.

The typical flying pattern during Cope Thunders was for pilots to familiarize themselves with the area for 1 – 2 days (range familiarization), followed by a 2 week exercise. Flight activity was anticipated to be most intense during the 2 week exercise period. Little flying activity was anticipated on weekends (Department of the Air Force 1995). During 2000, cancellation of Cope Thunders and closure of the Eielson Air Force air-strip reduced the number of Cope Thunder Exercises. If range familiarization flying and week ends are excluded from Cope Thunder dates, data were collected during 10 Cope Thunder days in 2000 and all these days were in the winter (March and April)(Table 3.1). In 2001, data were collected during 5 Cope Thunder days in the winter (March), 8 in the spring (May; and 5 of these 8 days were collected during the mitigation period), and 5 in the summer (July).

Table 3.1. Dates of Cope Thunder exercises in interior Alaska Military Overflight Areas and dates crews were in the field observing Dall's sheep and military overflights, during 2000 and 2001.

Year	**Cope Thunder Dates**	**Field Dates**
2000*	28 Feb. – 10 March	21 February – 5 March
	30 March – 14 April	10 – 21 April
	Cancelled	9 – 18 May
		15 – 21 July
2001	15 – 30 March	13 – 24 March
	3 – 18 May	6 – 16 May
	7 – 22 June (Cancelled)	7 – 21 June
	12 – 27 July	22 July – 2 August

* Eielson runway closed from May through September, 2000.

Behavior

All behavior observations focused on Dall's sheep ewe groups. Each day, field crews (typically 2 individuals) would hike from a base camp and attempt to locate ewe groups by using binoculars and scanning known sheep terrain. Once sheep were located, the field crew would move into an observation position. Observation positions were chosen based on a balance of minimizing disturbance to sheep and providing a clear view of sheep behavior. During sheep observations, one crew member would observe sheep using a spotting scope and the second would record data. Observations of sheep were made as early as 0700h and as late as 2000h but the majority of observations were made between 1000h and 1700h as military jet overflights were reported to be most concentrated at this time (Jim Hostman, USAF, personal communication). Data collected at the beginning of an observation session included temperature, wind speed and direction, precipitation, and distance from the sheep group to exposed rock. The "distance to exposed rock" was a subjective determination of potential escape terrain. All sheep within a group were classified by sex and age. For analysis, the numbers of "ewes" (ewes = ewes, young rams, and older lambs) in each group were enumerated and the numbers of young lambs were enumerated. Lambs were only categorized for analysis if they were less than 4 months old. Therefore, all statistical analyses in which lambs were included as a variable were restricted to May – August.

Dall's sheep behavior was recorded using scan sampling (Altman 1974) of the entire group. Behavior of each ewe and lamb in the group was categorized as: running, walking, feeding, standing, bedding, and other (active behavior including playing, socializing, grooming, etc.). The "other" category was not used in statistical analysis. Scan samples were taken every 10 minutes and continued until animals moved out of sight or until 1700h. In the event of an overflight, the observer would estimate when the aircraft was closest to the group and would scan to get an immediate response of the group to the overflight event. This event would reset the scan sampling schedule and the next scan would occur 10 minutes later or when another overflight event occurred, whichever came first. We did not choose to include a behavioral category of "vigilant or alert" in our activity budgets as have some researchers (Stockwell et al. 1991, Frid 1997) because our experience indicated that this was a difficult behavior to identify. We observed sheep that were apparently vigilant (head up with ears forward) while bedded and standing, when approached by other sheep, during spontaneous rock fall, while observing potential predators (wolverines, bears and humans), for no discernible reason, and when overflown by aircraft. We do not know if the energy expenditure during these "vigilant" periods is equivalent. In addition, there are no indications of how energetically costly it is to assume a vigilant posture as there are for the behavior categories we defined for this study (Fancy and White 1985). Possibly the behavior category of vigilance could be defined by linking it directly to a physiological response. Factors such as an elevated heart rate (MacArthur et al.1979, MacArthur et al. 1982, Weisenberger et al. 1996, Krausman et al. 1998,) would be optimal for defining vigilance. Stockwell et al. (1991) defined vigilance as a standing animal with head up. Based on this definition, our category of standing is synonymous with vigilant.

The ability to distinguish behavior categories of Dall's sheep varied with proximity to the sheep, terrain characteristics, and weather. Distance between observers and sheep varied but all observations were made within 1.5 km of the sheep. Rocky terrain was particularly problematic as sheep behind rocks were hidden from view and this may have positively biased our estimates of distance to rocky terrain for sheep groups.

The proportion of observed sheep engaged in specific activities were used for analysis and sheep that were out of view were not included in these proportions. Some activities are likely under-represented in scan samples. For example, bedded sheep were more likely to be out of sight than were standing animals. This bias however, was not restricted to a specific study site, year or timing relative to an overflight event.

Another issue to consider is the number of animals sampled during observation periods. In most instances, some sheep observed during one 2-week field effort were sampled repeatedly. In our analysis, we considered each day and each overflight event to be independent.

DATA ANALYSIS

Overflight Activity

We used paired *t*-tests to compare military and non-military overflights (total number and number per hour) observed during field sessions at Cirque Lake to overflights observed at West Point/Puzzle Gulch. *T*-tests were used to examine differences in the frequency of military and non-military overflights in the 2000 field season in comparison to the 2001 field season. All statistical tests were considered significant if $P \leq 0.05$.

Paired *t*-tests were used to compare the daily mean number of military overflights observed during Cope Thunder exercises to the mean number of military overflight events observed in either the 5 routine flying days before or the 5 routine flying days after these events (depending on which was available).

The daily number of military overflights observed at Cirque Lake during the mitigated time period was compared to the daily number observed during the same time period at West Point using paired *t*-tests.

Behavior

Dall's sheep behavior in relation to overflights was analyzed by following the steps outlined by Murphy et al. (1993). The number of animals engaged in each category of behavior was transformed to a percentage for each activity scan. Each scan was classified in relation to overflight history as: 1) within the 10 minute time period prior to an overflight event; 2) at the peak of the overflight event; 3) 10 minutes after the overflight, 4) undisturbed (no overflight event within 1 hour) or other (scan sample <1 hour of overflight but >10 minutes of overflight).

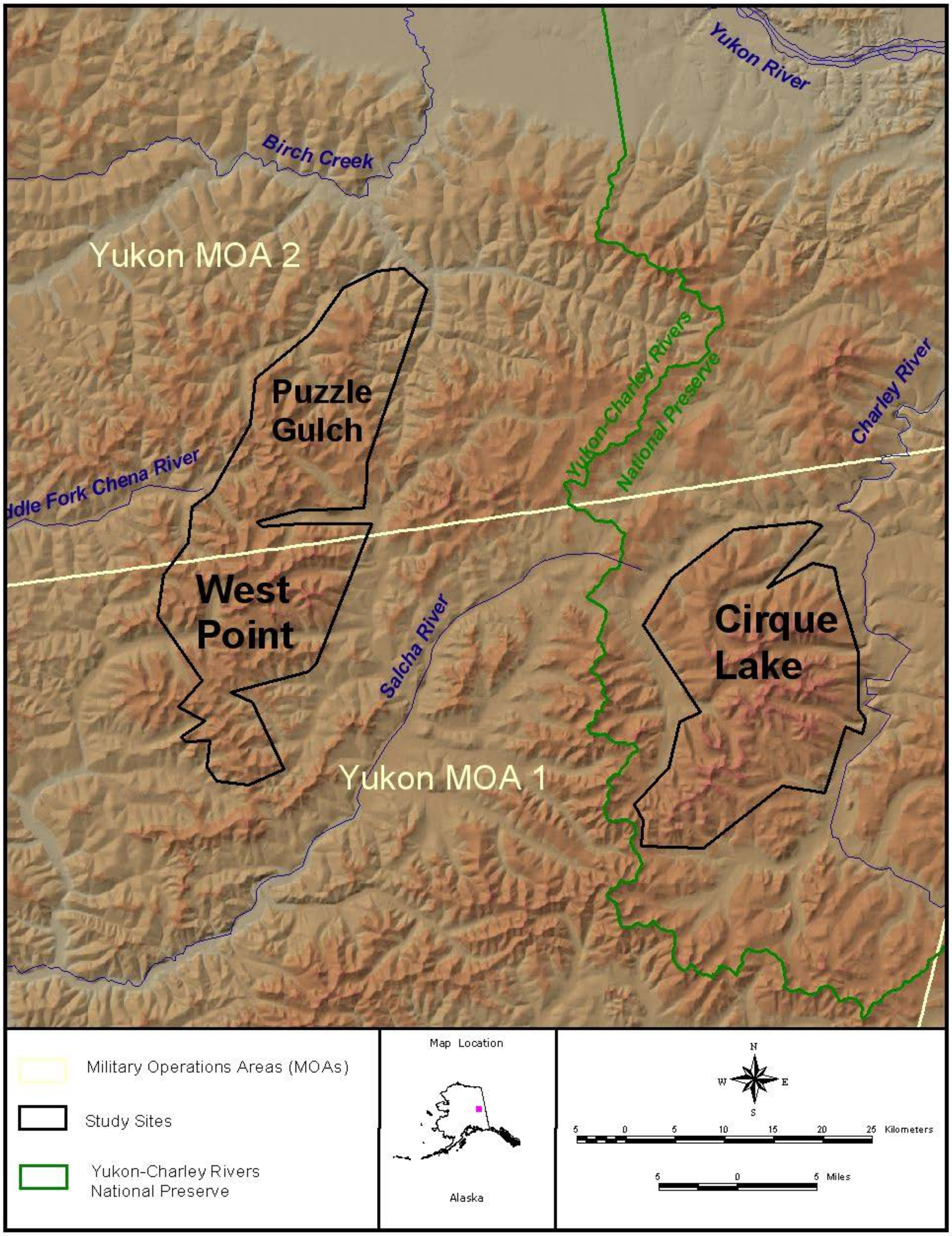


Figure 3.1. Location of study sites in interior Alaska and their relation to Military Operations Areas (MOAs). One study site is mitigated (Cirque Lake) for potential effects of low-level military jet overflights, and the other (West Point/Puzzle Gulch) is not. Dall’s sheep were observed and behavior was recorded at each of the 2 study sites during 4 two-week field sessions per year during 2000 and 2001.

Three measures of behavioral activity were used to examine Dall's sheep responses to overflights: 1) percent active (percent of animals during the scan that were standing, feeding, walking or running); 2) feeding efficiency (proportion of animals feeding divided by the sum of the proportion of animals feeding and standing: *sensu* Berger et al. 1983, Stockwell et al. 1991), and; 3) the proportion of animals engaged in bedding, standing, feeding, walking and running (behavior or activity budget). Dall's sheep reactions to overflights were examined using three levels of detail of overflight activity: 1) number of military overflights observed during the day ("day flight models"); 2) military overflight events (within 10 minutes before, during or 10 minutes after individual overflight events)("event models"), and 3) characteristics of individual military overflight events (proximity of overflight event and peak dBA level of overflight event; "sound models"). A subset of the event model data set was used to test sound models. Statistical tests in the event and sound models were considered significant if $P \leq 0.05$.

Because sheep activity may vary by season, and to match other analyses presented in this report, we divided observation data into date sequences as follows: February and March, 1 – 14 April, 15 – 30 April, 3 – 18 May, 19 May – June 1, 7 – 22 June, 12 – 27 July, 28 July – 11 August. Analyses that included the effects of lambs on Dall's sheep behavior were limited to May – August. We labeled models that included data from all date sequences and excluded lambs from the statistical analysis as "ewe models". Models restricted to May – August and that included the number of lambs in the groups as a covariate were labeled "lamb models".

Analysis of covariance (ANCOVA; GLM [SPSS Inc., Chicago Illinois]) was used to examine the effect of class variables (study site, year nested within study site, date sequence nested within year nested within study site, and the proximity of an overflight event) and covariates (number of ewes in the group, the number of lambs in the group, the distance of the group to rocky terrain, the number of military overflights observed per day, and the peak dBA of the overflight event) on the percent of sheep active and feeding efficiency of Dall's sheep.

Multiple analysis of covariance (MANCOVA; GLM [SPSS Inc., Chicago Illinois]) was used to examine the effects of class variables (study site, year nested within study site, date sequence nested within year nested within study site, and the proximity of an overflight event) and covariates (number of ewes in the group, the number of lambs in the group, the distance of the group to rocky terrain, the number of military overflights observed per day, and the peak dBA of the overflight event) on the proportions of sheep engaged in different activities (standing, feeding, bedded, walking, running). Significant MANCOVA results were examined using univariate tests of between subject effects to evaluate differences in specific behavior categories.

All models were evaluated with Type III sum of squares without interaction terms. Partial eta squared values were compared to evaluate the proportion of the total variability in the dependent variable explained by the independent variable (SPSS version 9.0 1999). A covariate effect was inferred if the significance ($P \leq 0.05$) of a class variable differed when comparing Type III and Type I sum of squares (Snedcor and Cochran 1989).

All data were examined for linearity, normality and homoscedasticity using scatter plots, residual plots, histograms and boxplots. It is common practice to transform percentage data using an arcsine square root transformation, and biological data (often approximating a Poisson distribution; Zar 1996) using a square root transformation (Zar 1996). The intent of data transformation is to more appropriately fit data to meet assumptions of statistical models. For this data set, transformations did not appear to improve data distribution. In addition, data transformation is not always desirable unless the largest variances are in the largest samples and the largest sample is more than 5 times the size of the smallest (Budescu and Applebaum 1981, Zar 1996), and this was not the case with this set of data. For these reasons, and to simplify the interpretation of results, none of the variables included in the ANCOVA and MANCOVA models were transformed.

RESULTS

Overflight Activity

There was no significant difference in the number of overflight events of all aircraft types observed at Cirque Lake in comparison to West Point ($t = 0.687$, $d.f. = 7$, $P = 0.514$). The number of total observed overflights varied between 12 at West Point from 21 February - 5 March of 2000, and 136 at Cirque Lake from 6 - 16 May 2001 (Fig 3.3). The total number of overflights observed in 2000 was 294, and in 2001 we observed 441 overflights.

An examination of strictly military overflights found no statistical difference ($t = 0.315$, $d.f. = 7$, $P = 0.76$) in the number of overflights observed when comparing Cirque Lake to West Point. The number of military overflights observed during a particular field session varied considerably from a low of 2 overflights to a high of 109. Both extremes occurred at Cirque Lake (Fig. 3.2). The number of military overflights we observed during 2000 was substantially less than observed in 2001 ($n = 92$ in 2000 and $n = 281$ in 2001). The military aircraft most commonly observed during overflight events was F-16s (15% of all military overflight events) followed by F-15s (8% of all military overflight

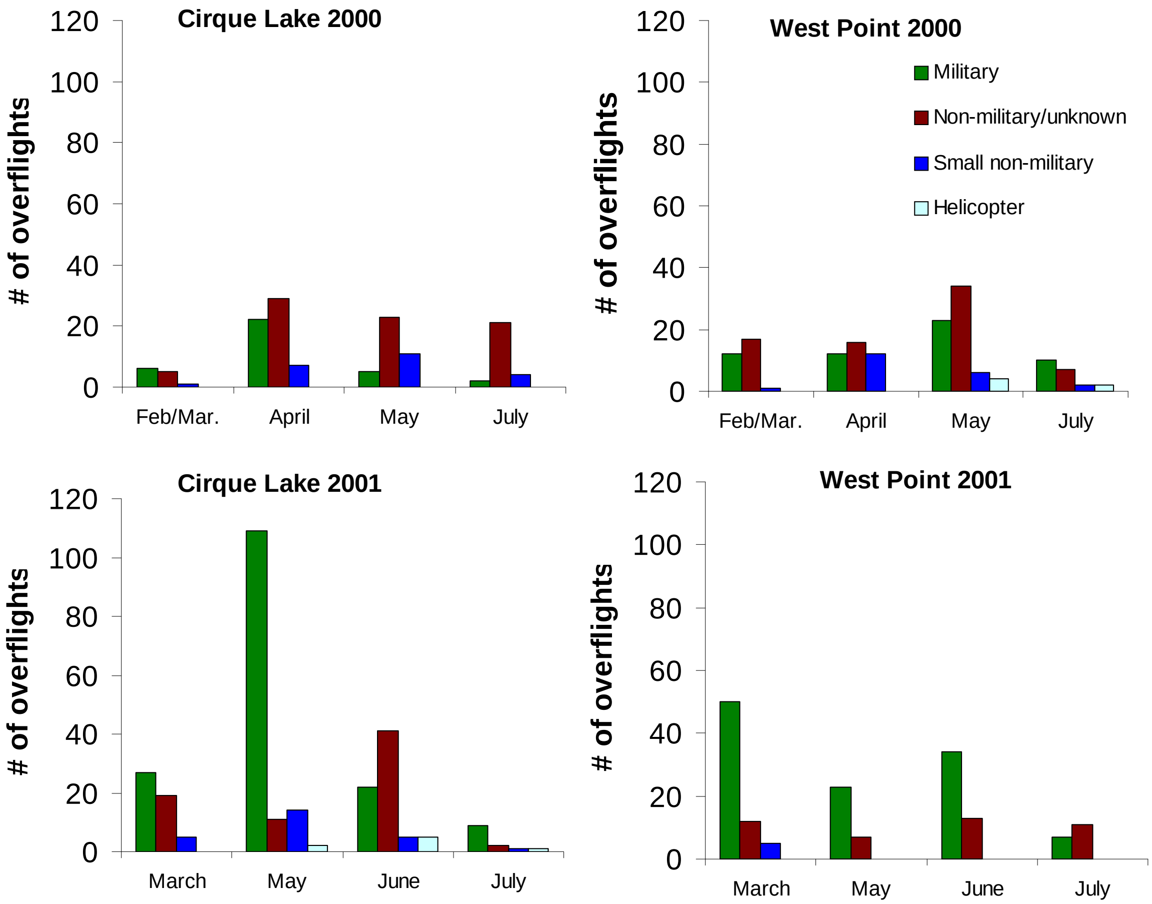


Figure 3.2. A comparison of the number of overflight events observed during the course of field studies in 2000 and 2001. Each field session lasted approximately 10 days (see Table 3.1). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. One study site (Cirque Lake) is mitigated for the impacts of low level military aircraft and the other (West Point/Puzzle Gulch) is not.

events) and A-10s (3% of all military overflight events). In most instances, military jets were distant enough that no accurate identification of aircraft type could be made. There was no difference in the number of military overflights observed when comparing the number of military overflights observed before or after Cope Thunder periods, to the number of military overflights observed during the Cope Thunder periods (t = 0.756, *d.f.* = 5, P = 0.48).

Sheep were not located every day while in the field. Because of this, no data were collected on the number of military overflight events observed over Dall's sheep in the 5 days prior to the start of the mitigation period at Cirque Lake during the May 2000 field work. In addition, no field work was done in June of that year. During 2001, a daily mean of 12 (n=4) military overflights were observed in the 5 days prior to the start of the mitigation period (May 10) at Cirque Lake and a daily mean of 20 (*n*=3) were observed in the 5 days after the initiation of the mitigation measures. In the 5 days prior to the cessation of the mitigation period at Cirque Lake (June 15), the mean daily number of military overflights observed was 5 (*n*=3) and in the 5 days following the cessation of the mitigation measures, the mean daily number of military overflights events observed while watching sheep was 2 (*n*=4). Therefore, in the 2 instances for which data were available, the number of overflight events observed at Cirque Lake was greater during the mitigation period then before or after. There were no statistical differences (t = 0.982, *d.f.* = 19, P = 0.34) in the mean ($\pm$SE) number of military overflights observed during the mitigation period over Cirque Lake (9 $\pm$2.3) in comparison to West Point (11 $\pm$2.0).

Military aircraft constituted 52% of the overflight activity observed above the Cirque Lake and West Point study sites (Table 3.2). The majority of the air traffic in these areas was above 1500 m and in the "far" category and this was true of military aircraft (84%) as well as non-military aircraft (75%). Low level overflights close to observed sheep were a relatively rare event (8% of all overflight events) and a rare event when only military overflights are considered (7% of all military flights; Table 3.2). During 2000 and 2001, few overflight events occurred during the mitigated time period and fewer still occurred during a Cope Thunder event that also occurred during a mitigated time period (Table 3.2). On average sheep were exposed to 42.9 military overflights per week and 3.1 of these were low and close.

Because of differences in the amount of time spent observing sheep between study sessions and between study sites, we examined the number of overflight events (all aircraft types) as a rate process (Table 3.3). In both study years, field crews observed fewer overflights per hour at Cirque Lake (1.12 and 1.17 overflight events per hour in 2000 and 2001, respectively) in comparison to West Point (1.22 and 1.24 overflight events per hour in 2000 and 2001, respectively). The difference between the study sites in the number of overflights observed per hour paired by field session was not significant (t = 0.634, *d.f.* = 7, P = 0.55). No difference was detected in the number of overflights observed per hour when comparing 2000 to 2001 (t = 0.288, *d.f.* = 14, P = 0.78).

Table 3.2. Number of overflight events by aircraft type and proximity to Dall's sheep observed while watching Dall's sheep behavior in interior Alaska during 2000 and 2001. Some of the overflight events occurred during Cope Thunder exercises, some occurred during a mitigated time period over a mitigated airspace (Cirque Lake from May 10-June 15), and some occurred during Cope Thunder exercises during the mitigated time period.

Aircraft type	Proximity	CT events[a]	Mitigated events[b]	CT & mitigated events	Total Events
Small non-military					
	Close	6	3	1	15
	Moderate	5	4	0	15
	Far	14	21	8	44
Military jet					
	Close	14	9	6	20
	Moderate	27	5	2	38
	Far	182	67	35	312
Military non-jet					
	Close	1	0	0	2
	Moderate	1	0	0	2
	Far	1	0	0	2
Helicopter					
	Close	2	3	2	4
	Moderate	0	0	0	2
	Far	1	0	0	8
Other[c]					
	Close	12	4	0	20
	Moderate	13	8	0	37
	Far	55	40	3	204

[a] Events that occurred during Cope Thunder dates.
[b] Events that occurred at the Cirque Lake study site during the mitigated time period (May 10-June15).
[c] Other includes unidentified aircraft (including commercial airlines).

Table 3.3. The amount of time spent observing Dall's sheep, the number of overflights (all types of aircraft), and the amount of time gathering sound level data during 2000 and 2001 at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. One study site (Cirque Lake) is mitigated for the impacts of low level military aircraft and the other (West Point/Puzzle Gulch) is not.

		Cirque Lake			West Point		
Year	Season	Obs. time (h)	Overflight per h	Sound time (h)	Obs. time (h)	Overflight per h	Sound time (h)
2000	Feb/March	11	1.0	11	18	1.67	17
	April	42	1.38	42	47	0.85	2
	May	44	0.89	39	40	1.68	37
	July	25	1.08	-	25	0.84	25
2001	March	44	1.16	22	58	1.24	14
	May	54	2.52	47	18	1.72	13
	June	103	0.71	-	27	1.74	25
	July	33	0.39	33	32	0.56	30

Sound

Sound level data were gathered with Dall's sheep observations for over 360 hours. Success in collecting sound level data varied considerably from one outing to the next (Table 3.3). Environmental factors and equipment malfunction resulted in the loss of a substantial amount of data. In the July 2000 and the June 2001 field sessions at Cirque Lake no sound data were collected. At West Point during April 2000, just 2 hours of sound data were retrieved.

The loudest overflight events experienced by observers while watching sheep were due to military jet aircraft and only military aircraft produced sound levels $\geq$ 90dBA (Table 3.4). Peak sound events $\geq$ 90dBA occurred at Cirque Lake on 9 May 2001 (112 dBA; 2 unidentified aircraft with a sonic boom) and 14 May 2001 (95 dBA; 2 F-15s). At West Point, peak sound events $\geq$ 90dBA occurred on 14 May 2001 (91 and 98 dBA; 2 events both by unidentified aircraft), on 11 June 2001 (132 dBA produced by four F-16 aircraft and 92 dBA produced by one F-16 aircraft), on 18 June 2001 (96 and 98 dBA; 2 events both by four F-16 aircraft), and on 23 July 2001 (92 dBA; 1 event by unknown military aircraft).

Table 3.4. Minimum and maximum sound levels measured during overflight events in interior Alaska during 2000 and 2001. Overflight events were classified into 1 of 5 different aircraft type categories for analysis.

Aircraft type	Sound metric	Sample size (*n*)	Min. dBA	Max. dBA
Small non-military				
	2 min. mean (L_{eq})	44	18	71
	2 min. Peak (L_{max})	44	27	82
Military jet				
	2 min. mean (L_{eq})	225	18	82
	2 min. Peak (L_{max})	225	22	132
Military non-jet				
	2 min. mean (L_{eq})	1	29	29
	2 min. Peak (L_{max})	1	51	51
Helicopter				
	2 min. mean (L_{eq})	9	23	51
	2 min. Peak (L_{max})	9	30	78
Other [a]				
	2 min. mean (L_{eq})	134	18	59
	2 min. Peak (L_{max})	133	20	84

[a] Other includes commercial airliners and unidentified aircraft.

Few military overflight events produced sound levels greater that 70 dBA. Sound events greater than 70 dBA occurred more frequently at Cirque Lake in comparison to West Point in a given year and sound events greater than 50 dBA occurred more commonly in 2001 in comparison to 2000 (Table 3.5).

Table 3.5. Number of occurrences of sound levels measured during overflight events while observing sheep in interior Alaska MOAS in 2000 and 2001.

Year	dBA	Cirque Lake (Frequency)		West Point (Frequency)	
		2 min. Peak	2 min. mean	2 min. Peak	2 min. mean
2000	41 - 50	12	17	21	26
	51 - 60	7	3	8	6
	61 - 70	1	5	4	3
	≥ 71	6	1	3	1
2001	41 - 50	10	55	4	51
	51 - 60	26	28	13	19
	61 - 70	17	4	29	4
	≥ 71	34	0	30	2

Behavior in Relation to Daily Military Overflight Activity

Dall's sheep were observed for over 600 hours (Table 3.3). During 2000, a total of 121 h were spent observing sheep at Cirque Lake and 130 h were spent observing sheep at West Point. In 2001, more total time was spent observing sheep at Cirque Lake (233 h) in comparison to West Point (135 h) because of differences in success locating sheep. Examining time spent during each field session (4 per year), comparable amounts of time were spent observing sheep at Cirque Lake and West Point in 2000; $t = 0.861$, $d.f. = 3$, $P = 0.45$). In 2001, differences spent observing sheep during field sessions between Cirque Lake and West Point were not statistically significant ($t = 1.22$, $d.f. = 3$, $P = 0.31$). Of particular note, however, is the large amount of time spent observing sheep in the June field session at Cirque Lake (Table 3.3).

The number of overflights observed while watching sheep did not significantly affect the percent of time Dall's sheep ewes spent active (Table 3.6). Factors that did significantly affect the amount of time Dall's sheep ewes were active, in models that included the number of overflights observed, were the distance ewes were from rocky terrain, year, and the date sequence ($P<0.025$; Table 3.6). Sheep became more active the farther they were from rocks, and sheep were more active in 2001 in comparison to 2000. Although date sequence was significant in explaining the proportion of ewes active, no trend is apparent (Fig. 3.3). As the number of ewes in the group increased, the proportion of sheep active in the group also increased significantly in ewe models (Table 3.6). Date sequence accounted for the greatest amount of variation (4% and 2% for ewe and lamb models, respectively) in the amount of time Dall's sheep spent active when compared to the other explanatory variables, followed by year (1% for ewe and lamb models). Little of the variation in the proportion of time Dall's sheep spent active was explained by the independent variables in the ANCOVA models (Table 3.6). Study site and year interacted with the covariates of rock and ewe (Fig. 3.4).

Table 3.6. Summary of ANCOVA results examining factors affecting the proportion of time Dall's sheep were active during field sessions in 2000 and 2001. The number of military aircraft observed while observing sheep was used as a measure of military aircraft activity. We examined 2 models. The first model was examined without considering the presence of lambs, and a second model (restricted to May - July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point).

Dependent variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Proportion Active (ewe/day flight model)					
	Rock	1	7.309	0.007	0.003
	Ewe	1	10.246	0.001	0.005
	Day flight	1	0.766	0.382	0.000
	Site	1	1.855	0.173 [a]	0.001
	Year(site)	2	7.525	0.001 [a]	0.007
	Sequence(year(site))	15	5.718	0.000	0.039
Proportion Active (lamb/day flight model)					
	Rock	1	7.653	0.006	0.006
	Ewe	1	1.083	0.298	0.001
	Lamb	1	0.376	0.540	0.000
	Day flight	1	0.898	0.344	0.001
	Site	1	0.366	0.545 [a]	0.000
	Year(site)	2	5.827	0.003 [a]	0.009
	Sequence(year(site))	7	4.480	0.000	0.024

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) number of military overflights observed during the day; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

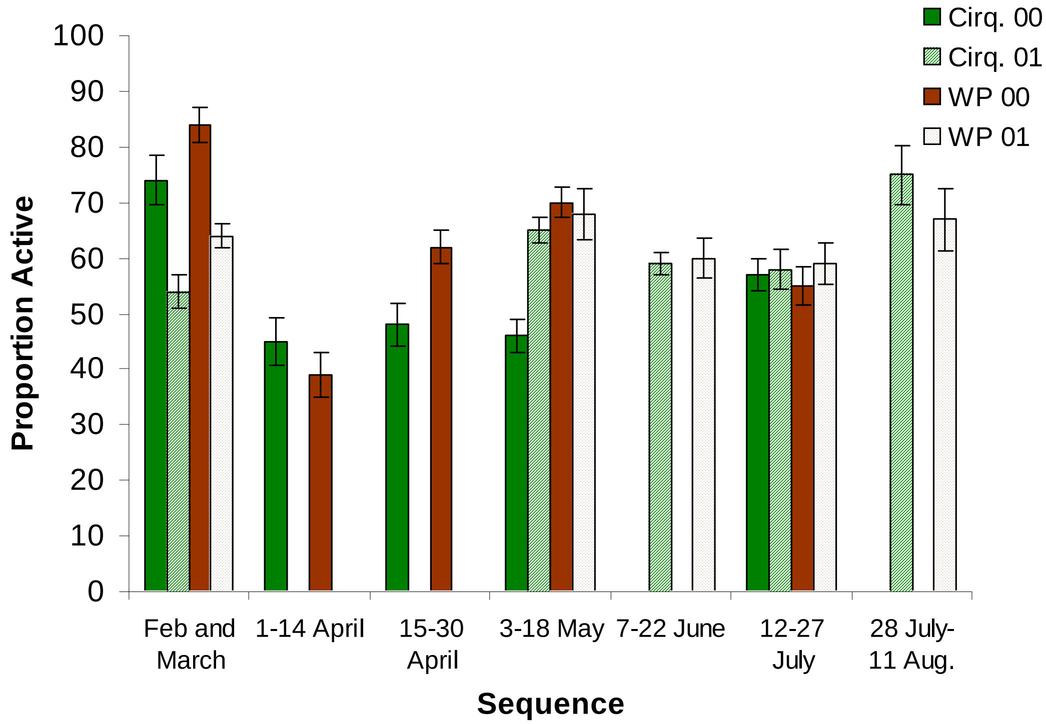


Figure 3.3. Mean (±SE) proportion of sheep active during scan samples during the course of field observations in 2000 and 2001. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point). Data were not collected for every sequence during both years.

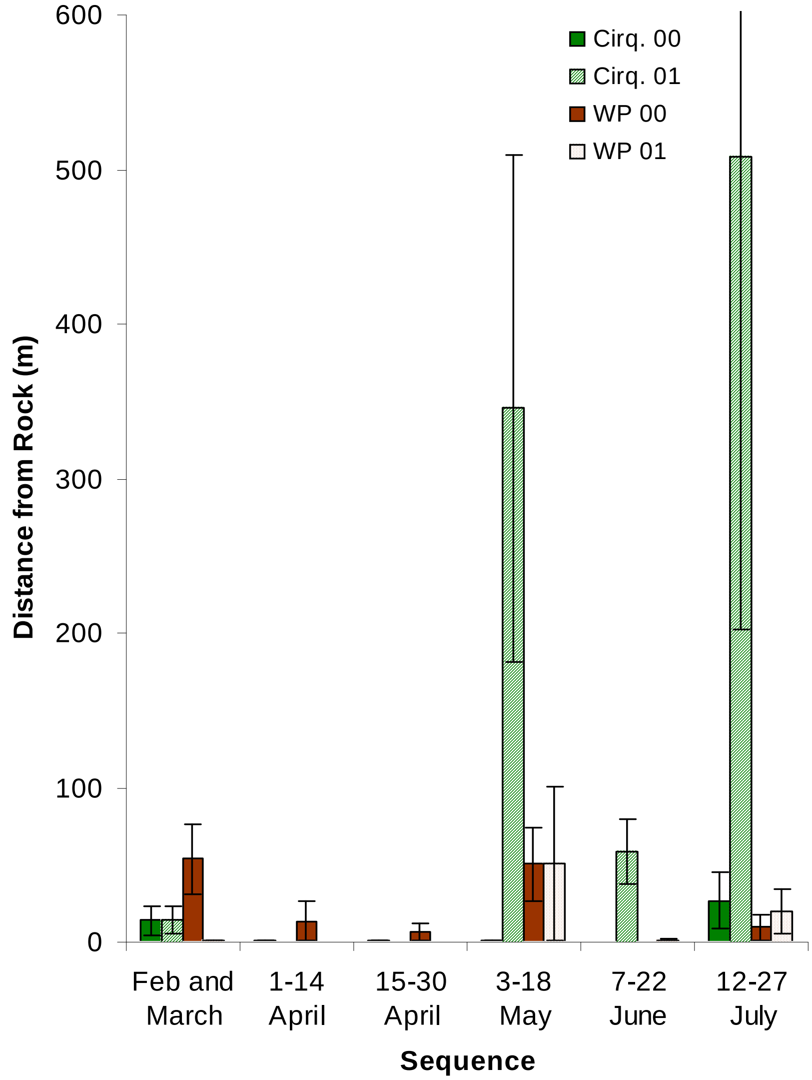


Figure 3.4. Mean (+SE) distance from rock observed in sheep bands at the start of observation periods during the course of field studies in 2000 and 2001. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point). Data were not collected for every sequence during both years.

The number of overflights observed while watching sheep did not significantly affect the feeding efficiency of Dall's sheep ewes (Table 3.7). Dall's sheep feeding efficiency in the ewe/day flight model was positively associated with the distance ewes were from rocks and the number of ewes in the group (Table 3.7). Sheep at West point had a significantly higher feeding efficiency than those at Cirque Lake (0.76 and 0.73, respectively) in ewe/day flight models. Date sequence was significant in the ewe/day flight model in explaining feeding efficiency and was highest before April 1 (0.79) and lowest from 1-14 April (0.58) (Fig. 3.5). In the lamb/day flight model, distance from rocks and number of ewes in the group were positively associated with feeding efficiency and number of lambs in the group were negatively associated with feeding efficiency. In the lamb/day flight model, feeding efficiency was highest from 3-18 May (0.76) and lowest from 12-27 July (0.72) and although feeding efficiency was significantly related to date sequence, no consistent trend was apparent (Fig. 3.5). Mean feeding efficiency was higher at West Point (0.75) in comparison to Cirque Lake (0.73) and was higher in 2000 (0.75) in comparison to 2001 (0.73) but the magnitude of these differences was very small. Trends in feeding efficiency were not obvious comparing feeding efficiency across study sites, years, and date sequences (Fig. 3.5). Date sequence accounted for the greatest amount of variation (5% and 2% for ewe/day flight and lamb/day flight models, respectively) in the feeding efficiency of Dall's sheep when compared to other independent variables. Little of the variation in feeding efficiency of Dall's sheep was explained by the independent variables in day flight ANCOVA models (Table 3.7).

Table 3.7. Summary of ANCOVA results examining factors affecting the feeding efficiency of Dall's sheep during field sessions in 2000 and 2001. The number of military aircraft observed while observing sheep was used as a measure of military aircraft activity. We examined 2 models. The first model was examined without considering the presence of lambs, and a second model (restricted to May - July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point).

Dependent variable	Independent variable*	*d.f.*	*F*	*P*	Partial eta squared
Feeding Efficiency (ewe/day flight model)	Rock	1	5.548	0.019	0.004
	Ewe	1	6.256	0.012	0.004
	Day flight	1	1.122	0.290	0.001
	Site	1	5.901	0.015	0.004
	Year(site)	2	0.321	0.725	0.000
	Sequence(year(site))	15	5.233	0.000	0.049
Feeding Efficiency (lamb/day flight model)	Rock	1	7.293	0.007	0.008
	Ewe	1	6.782	0.009	0.007
	Lamb	1	3.912	0.048	0.004
	Day flight	1	0.981	0.322	0.001
	Site	1	0.606	0.437	0.001
	Year(site)	2	2.021	0.133	0.004
	Sequence(year(site))	7	2.199	0.032	0.016

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) number of military overflights observed during the day; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

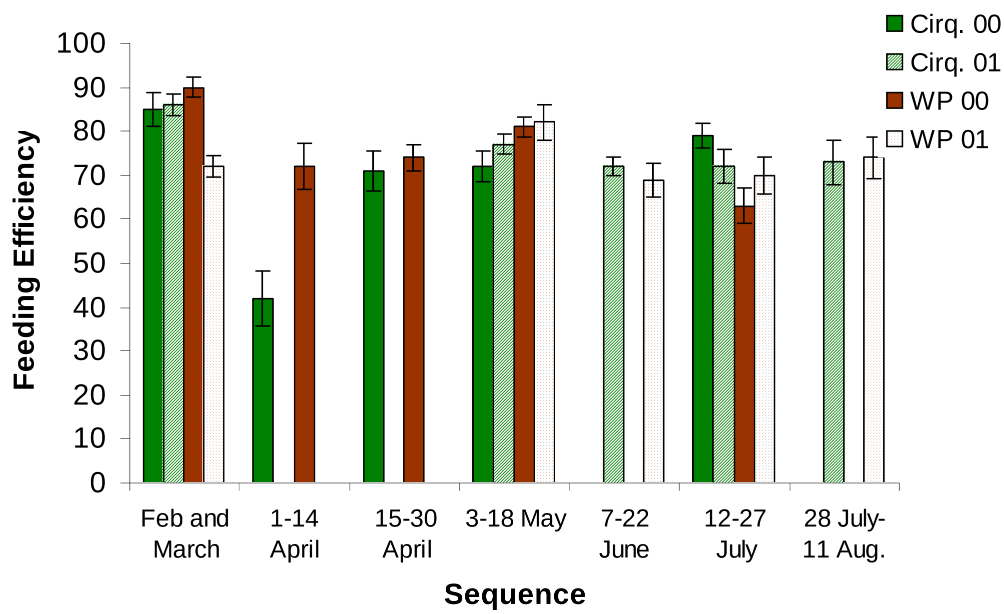


Figure 3.5. Feeding efficiency (±SE) of Dall's sheep during scan samples during the course of field observations in 2000 and 2001. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point). Data were not collected for every sequence during both years.

The number of overflights observed while watching sheep did not significantly affect the behavior of Dall's sheep ewes (Table 3.7). Dall's sheep behavior in day flight MANCOVA models was significantly affected by year and date sequence (Table 3.8). The number of ewes in the group significantly affected behavior in the ewe/day flight MANCOVA model (Table 3.8). The distance to rock had a significant effect on behavior in the lamb/day flight MANCOVA model. Study site was found to have a significant effect on behavior in ewe/day flight MANCOVA models (Table 3.8). Date sequence accounted for the greatest amount of variation (2-3%) in behavior of Dall's sheep when compared to the other independent variables in the models (Table 3.8). The majority of the variation in behavior of Dall's sheep was not explained by the independent variables in the MANCOVA models (Table 3.8).

Differences in behavior between years in the ewe/day flight model (Table 3.8) was due to differences in the proportion of ewes bedded (P=0.001) and walking (P<0.001). A greater proportion of sheep were observed bedded in 2000 in comparison to 2001 in ewe models and a smaller proportion of sheep were observed walking in 2000 in comparison to 2001 in the ewe model.

Significant differences between date sequences existed in the ewe model (Table 3.8) for the proportion of sheep bedded (P<0.001), feeding (P<0.001) and walking (P<0.001). Although significant differences occurred in behavior categories across date sequences, no chronological pattern was obvious (Fig.3.6; Table 3.8).

The differences in behavior associated with the number of ewes in the group (Table 3.8) was due to differences in the proportion of sheep feeding and bedded. As the number of ewes in the group increased so did the proportion of animals feeding (*P*<0.001). In ewe models, a smaller proportion of sheep were observed bedded with increasing numbers of ewes in the group (*P*=0.001).

Table 3.8. Summary of MANCOVA results examining factors affecting the behavior of Dall's sheep (percent bedding, standing, feeding, walking, and running) during field sessions in 2000 and 2001. We examined 2 models. The first model was examined without considering the presence of lambs, and a second model (restricted to May - July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point).

Dependent Variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Behavior					
(ewe/day flight	Rock	5	2.175	0.054	0.005
model)	Ewe	5	3.508	0.004	0.008
	Day flight	5	1.951	0.083	0.005
	Site	5	3.045	0.010	0.007
	Year(site)	10	3.978	0.000	0.009
	Sequence(year(site))	75	4.35	0.000	0.030
Behavior					
(lamb/day flight	Rock	5	2.701	0.020	0.010
model)	Ewe	5	2.017	0.074	0.008
	Lamb	5	2.495	0.029	0.010
	Day flight	5	1.552	0.171	0.006
	Site	5	1.925	0.087	0.007
	Year(site)	10	4.126	0.000	0.016
	Sequence(year(site))	35	3.243	0.000	0.017

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) number of military overflights observed during the day; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

In ewe/day flight models, behavior by sheep at the 2 study sites was significantly different but univariate tests did not indicate significant differences in specific behavioral categories (Table 3.8).

For lamb/day flight models, a smaller proportion of Dall's sheep were observed bedded (*P*=0.006) and a smaller proportion were standing (*P*=0.007) the greater distance sheep were from rocks. As the number of lambs in groups increased a greater proportion of sheep were observed walking (*P*= 0.031) in the lamb/day flight model. Differences in behavior between years in the lamb/day flight model (Table 3.8) were due to differences in the proportion of sheep bedded (*P*=0.003), standing (*P*=0.025) and walking (*P*=0.002). A greater proportion of sheep were observed bedded in 2000 in comparison to 2001 in the lamb/day flight model and a smaller proportion of sheep were observed standing and walking in 2000 in comparison to 2001 in the lamb/day flight model (Table 3.8). Significant differences between date sequences existed in the lamb/day flight model (Table 3.8) for the proportion of sheep bedded (*P*<0.001), feeding (*P*=0.005) and walking (*P*<0.001). No chronological patterns in behavior categories across date sequences were obvious (Fig.3.6; Table 3.9).

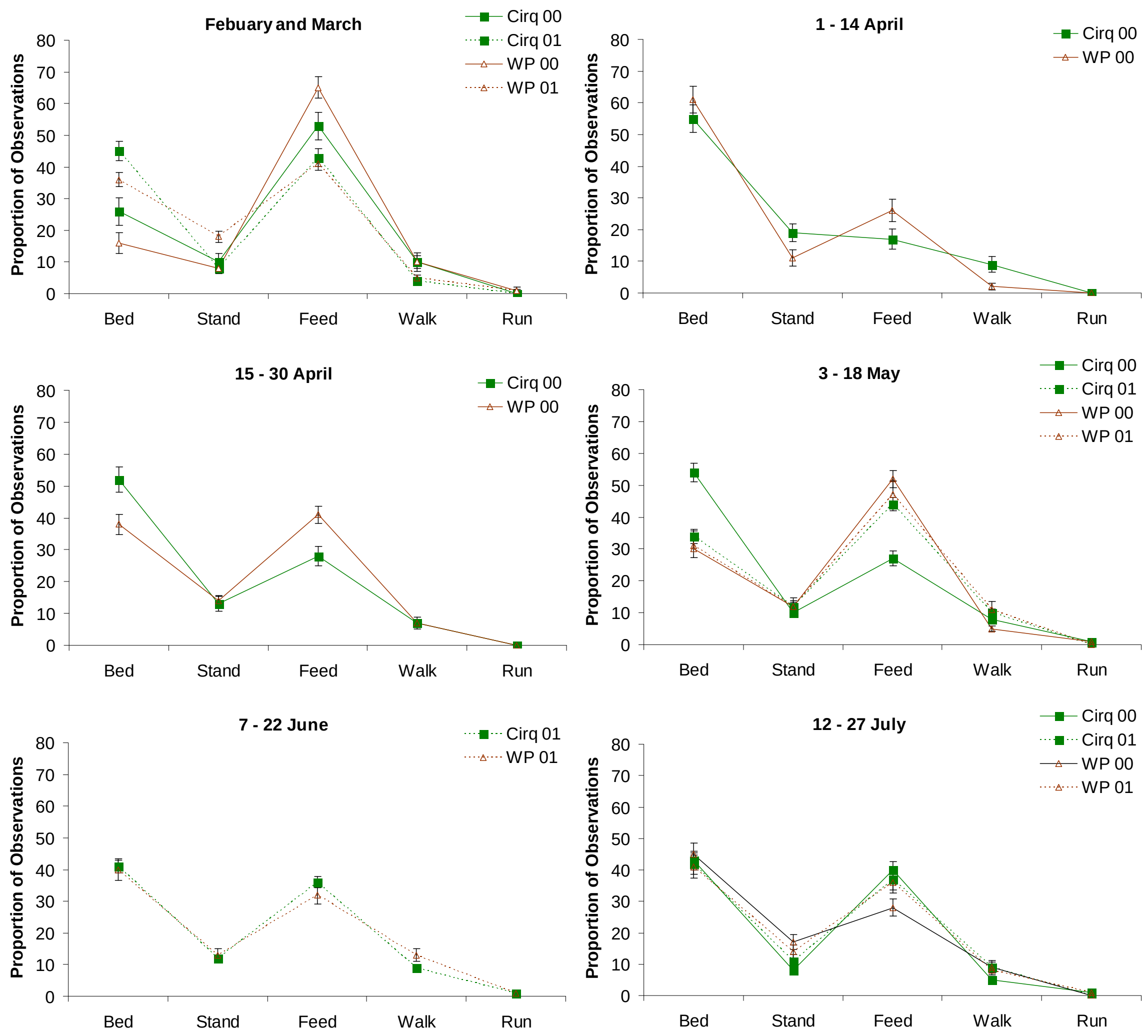


Figure 3.6. Mean (±SE) behavior of Dall's sheep from scan samples during the course of field observations in 2000 and 2001. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska (Cirq = Cirque Lake and WP = West Point). Data were not collected for every sequence during both years.

Behavior in Relation to Military Overflight Events

Although there was a tendency for activity to increase during, and 10 minutes after an overflight event (Fig. 3.7), this result was not significant (Table 3.9).Factors that significantly affected the proportion of Dall's sheep active during scan samples were the year and the date sequence during the year (*P*<0.05; Table 3.9) in the ewe/overflight model and in the lamb/overflight model. Sheep were more active in 2001 in comparison to 2000 in overflight models. Sheep were most active 7-22 June and least active 12-27 July and no sequential trend was apparent for date sequence and activity. Date sequence accounted for the greatest amount of variation (13% and 12%, for ewe/overflight and lamb/overflight models, respectively) in the proportion of Dall's sheep active when compared to the other independent variables. Little of the variation in the amount of time Dall's sheep spent active in overflight models was explained by the independent variables in the ANCOVA models (Table 3.9). There were no interactions of class variables with covariates (rock, ewe, lamb) (Table 3.9).

Table 3.9. Summary of ANCOVA results examining factors affecting the proportion of time Dall's sheep were active including the effect of military overflight events during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Proportion Active (ewe/overflight model)	Rock	1	3.308	0.069	0.006
	Ewe	1	3.152	0.076	0.005
	Overflight	2	1.408	0.245	0.005
	Site	1	3.204	0.074	0.006
	Year(site)	2	3.338	0.036	0.012
	Sequence(year(site))	15	5.918	0.000	0.134
Proportion Active (lamb/overflight model)	Rock	1	3.295	0.070	0.009
	Ewe	1	2.844	0.093	0.008
	Lamb	1	0.088	0.767	0.000
	Overflight	2	1.128	0.325	0.006
	Site	1	3.325	0.069	0.009
	Year(site)	2	5.875	0.003	0.031
	Sequence(year(site))	7	6.766	0.000	0.115

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after an overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

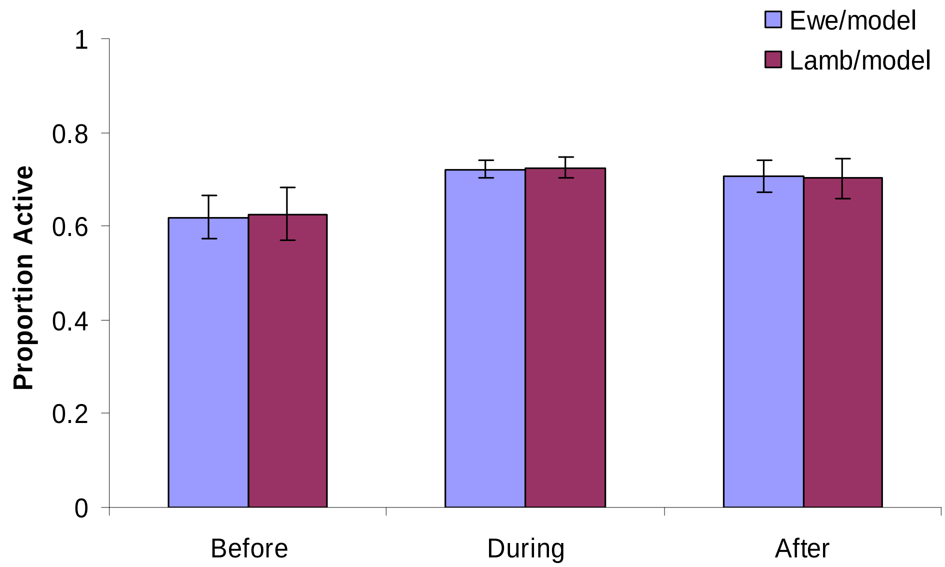


Figure 3.7. Mean (±SE) proportion of Dall's sheep active during scan sampling in: 1) the 10 minutes before a military overflight event (*n*=85 for ewe model and *n*=55 for lamb model); 2) during a military overflight event (*n*=375 for ewe model and *n*=245 for lamb model); and 3) 10 minutes after the overflight event (*n*=135 for ewe model and *n*=82 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Dall's sheep feeding efficiency was significantly affected by overflight events (Table 3.10; Fig. 3.8). The significant differences in feeding efficiency occurred when comparing feeding efficiency before the overflight to the feeding efficiency after the overflight (P= 0.001) for the ewe/overflight model. For the lamb/overflight model, there were significant differences in feeding efficiency comparing before to during overflight events (P= 0.028) and when comparing before to after overflight events (P= 0.028). In the ewe/overflight model, date sequence was significant. As the number of lambs in groups increased in the lamb/overflight models, feeding efficiency significantly declined. Date sequence accounted for the greatest amount of variation (5% and 3%, for ewe/overflight and lamb/overflight models, respectively) in the feeding efficiency of Dall's sheep when compared to the other independent variables. Overflight events accounted for 3% of the variation in feeding efficiency models. The majority of the variation in feeding efficiency of Dall's sheep was not explained by the independent variables in the ANCOVA overflight models (Table 3.10). The class variables of year and sequence interacted with the covariates (rock, ewe, lamb) in the ewe/overflight model. In the lamb/overflight model no indication of interactions of class variables with covariates were indicated.

Table 3.10. Summary of ANCOVA results examining factors affecting the feeding efficiency of Dall's sheep including the effect of military overflight events during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent variable*	*d.f.*	*F*	*P*	Partial eta squared
Feeding Efficiency (ewe/overflight model)	Rock	1	0.455	0.500	0.001
	Ewe	1	0.133	0.716	0.000
	Overflight	2	5.660	0.004	0.025
	Site	1	0.166	0.684	0.000
	Year(site)	2	0.427	0.652 [a]	0.002
	Sequence(year(site))	15	1.731	0.042 [a]	0.055
Feeding Efficiency (lamb/overflight model)	Rock	1	0.150	0.698	0.001
	Ewe	1	2.054	0.153	0.007
	Lamb	1	5.134	0.024	0.017
	Overflight	2	3.738	0.025	0.025
	Site	1	1.103	0.294	0.004
	Year(site)	2	0.466	0.628	0.003
	Sequence(year(site))	7	1.310	0.245	0.031

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after an overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

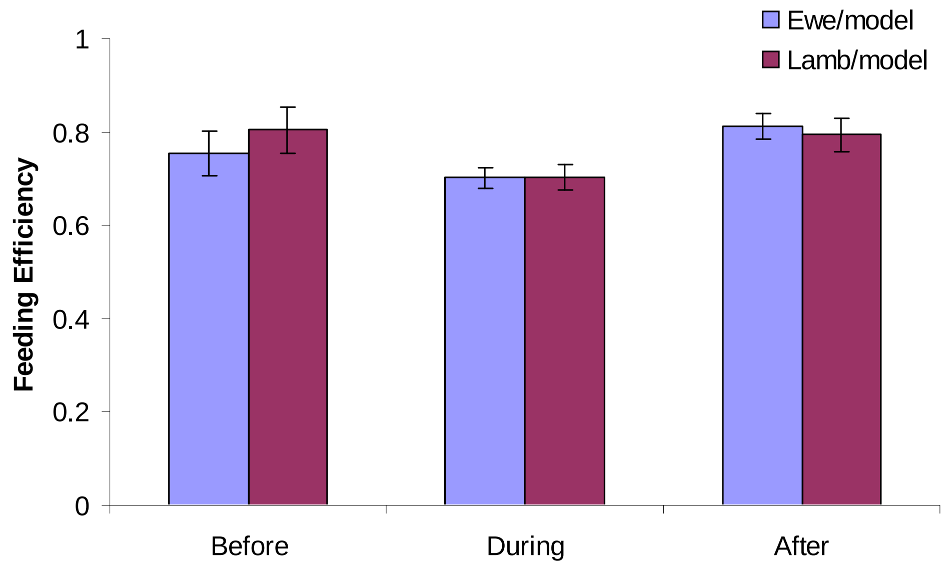


Figure 3.8. Mean (±SE) feeding efficiency of Dall's sheep during scan sampling in: 1) the 10 minutes before a military overflight event (*n*=63 for ewe model and *n*=41 for lamb model); 2) during a military overflight event (*n*=305 for ewe model and *n*=201 for lamb model); and 3) 10 minutes after the overflight event (*n*=105 for ewe model and *n*=65 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Although there was a suggestion of differences in behavior before, during and after overflight events, these results were not statistically significant (Fig. 3.9). Observed Dall's sheep tended to be bedded more with in the 10 minutes before an overflight event than they were during or 10 minutes after an overflight event. Observed Dall's sheep tended to walk more during and 10 minutes after an overflight event in comparison to before the overflight event (Fig. 3.9).

There were significant differences in behavior of Dall's sheep associated with the number of ewes in groups (Table 3.11). In the ewe/overflight model, univariate tests did not indicate significant differences in specific behavioral categories. In the lamb/overflight model, the proportion of ewes feeding increased as the number of ewes increased (P=0.046).

There was a significant difference in the behavior of Dall's sheep associated with the number of lambs in the group (Table 3.11). A greater proportion of animals were standing (P= 0.025) as the number of lambs in groups increased. In addition, a smaller proportion of sheep were observed feeding as the number of lambs in the group increased (P= 0.008) in the lamb/overflight MANCOVA models.

Significant differences between date sequences existed in ewe/overflight and lamb overflight MANCOVA models (Table 3.11). In the ewe/overflight model, significant differences were detected in the proportion of sheep bedded (P<0.001), feeding (P<0.001), and walking (P<0.001). In the lamb/overflight model, significant differences were detected in standing

(*P*<0.001), feeding (*P*<0.001) and running (*P*<0.001). Although significant differences occurred in behavior categories across date sequences, no chronological pattern was obvious (Fig. 3.6).

The class variable year interacted with covariates (rock, ewe, lamb) in the ewe/overflight and the lamb/overflight (Table 3.11).

The number of ewes in the group explained the most variation in behavior of Dall's sheep in the ewe/overflight model (6%) and the number of lambs in the group explained the most variation in the lamb/overflight model (5%). Less than 25% of the variation in Dall's sheep behavior observed was accounted for by the independent variables we used to construct overflight event models (Table 3.11).

Table 3.11. Summary of MANCOVA results examining factors affecting the behavior of Dall's sheep (percent bedding, standing, feeding, walking, and running) including the effect of military overflight events during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent Variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Behavior ewe/overflight model	Rock	5	2.058	0.069	0.018
	Ewe	5	7.401	0.000	0.061
	Overflight	10	1.692	0.078	0.015
	Site	5	0.715	0.613	0.006
	Year(site)	10	1.408	0.171 [a]	0.012
	Sequence(year(site))	75	2.305	0.000	0.059
Behavior (lamb/overflight model)	Rock	5	1.507	0.187	0.020
	Ewe	5	2.287	0.046	0.031
	Lamb	5	4.117	0.001	0.054
	Overflight	10	1.369	0.190	0.019
	Site	5	1.173	0.322	0.016
	Year(site)	10	1.773	0.062 [a]	0.024
	Sequence(year(site))	35	2.275	0.000	0.042

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after an overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site
[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.

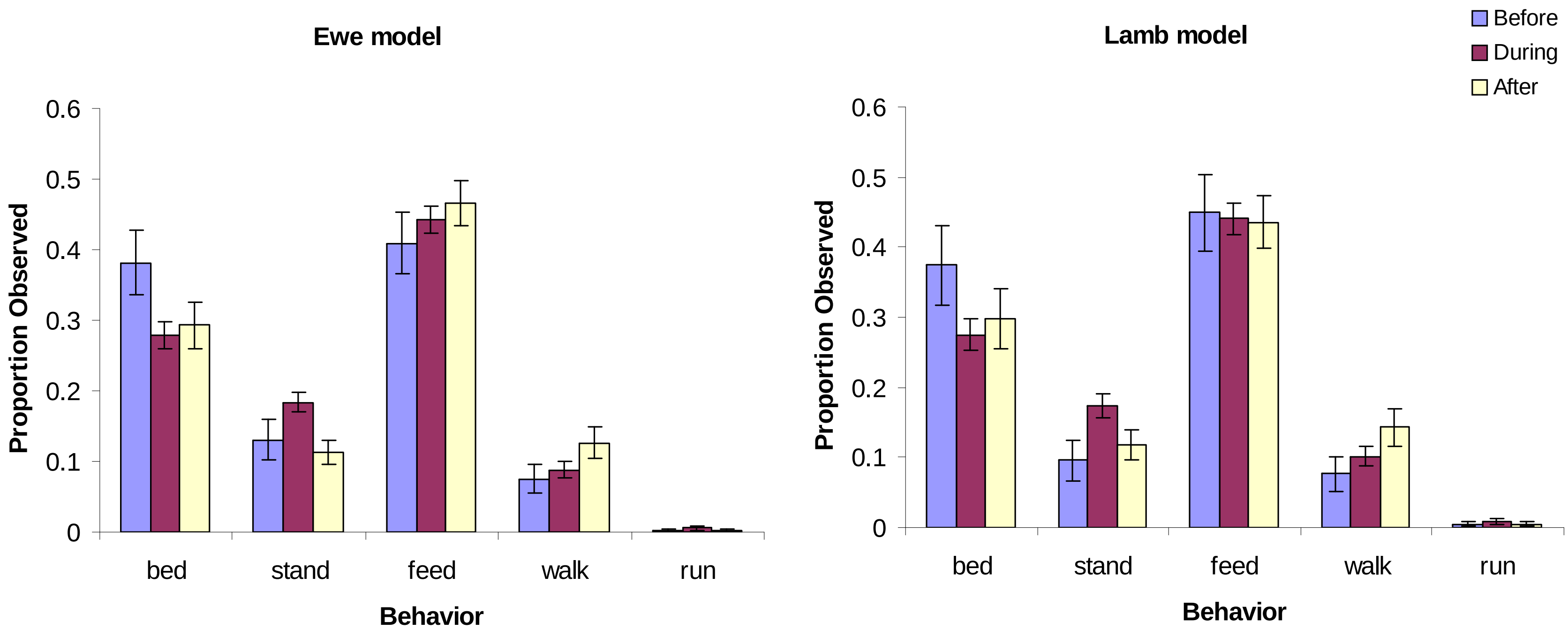


Figure 3.9. Mean (±SE) behavior of Dall's sheep during scan sampling in: 1) the 10 minutes before a military overflight event (*n*=85 for ewe model and *n*=55 for lamb model); 2) during a military overflight event (*n*=375 for ewe model and *n*=245 for lamb model); and 3) 10 minutes after the overflight event (*n*=135 for ewe model and *n*=82 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

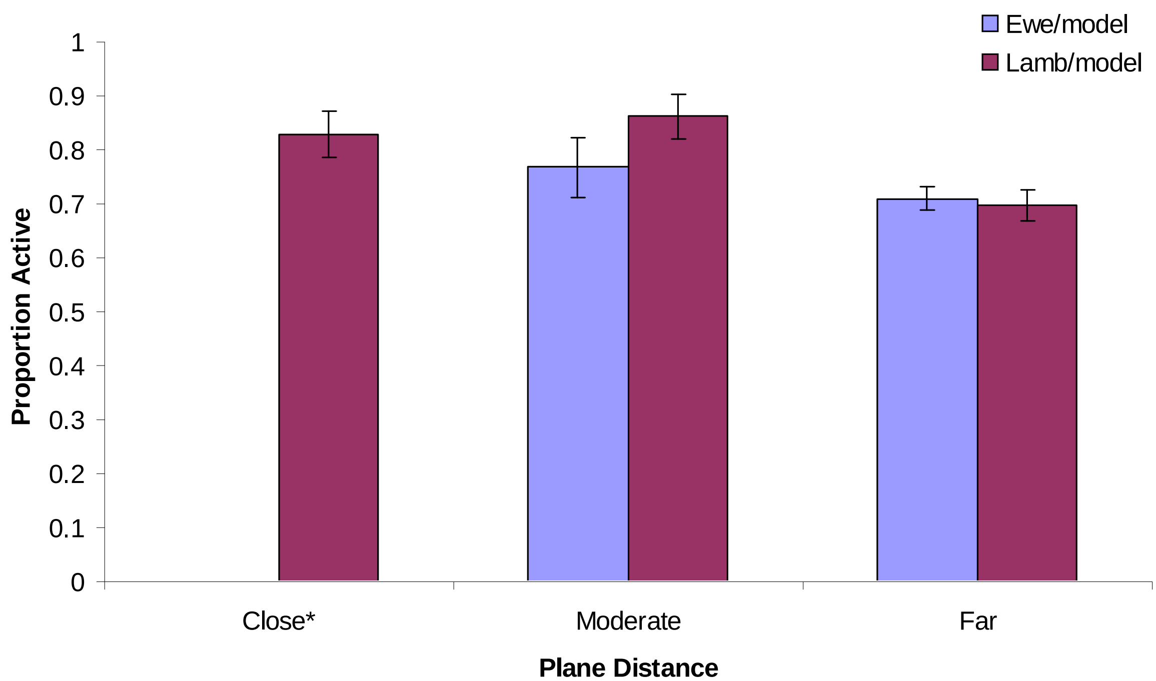
Behavior in Relation to Proximity and Peak Sound Level of Military Overflight Events
In the lamb/sound model, as the overflights became closer more sheep were active, (Fig. 3.10; Table 3.13). As sound levels (2 min. mean L_{eq}) increased, a higher proportion of sheep were active (*P*= 0.012 and *P*=0.046 for ewe/sound and lamb/sound models, respectively) (Fig. 3.11). Date sequence was also significantly (*P*<0.05) related to the proportion of Dall's sheep active in both the ewe/sound and lamb/sound models but no trend was apparent. In the lamb model, a greater proportion of sheep were active the farther they were from the rocks (Table 3.12). Date sequence accounted for the greatest amount of variation (20% and 12%, for ewe/sound and lamb/sound models, respectively) in the proportion of Dall's sheep active when compared to the other independent variables (Table 3.12). Independent variables entered into the ewe/sound and lamb/sound models explained 31% and 29% of the variation in the proportion of time sheep were active. Year interacted with the covariates (rock, ewe, L_{eq} [dBA], lamb) in the ewe/overflight and the lamb/overflight models (Table 3.12).

Table 3.12. Summary of ANCOVA results examining factors affecting the proportion of time Dall's sheep were active including proximity and sound level (2 min. mean L_{eq} [dBA]) of military overflights during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Proportion Active (ewe/sound model)	Rock	1	3.676	0.057	0.018
	Ewe	1	0.471	0.493	0.002
	L_{eq} (dBA)	1	6.386	0.012	0.031
	Proximity	3	1.613	0.188	0.023
	Site	1	1.267	0.262	0.006
	Year(site)	2	2.619	0.075 [a]	0.025
	Sequence(year(site))	11	4.705	0.000	0.204
Proportion Active (lamb/sound model)	Rock	1	4.042	0.046	0.026
	Ewe	1	1.549	0.215	0.010
	Lamb	1	1.266	0.262	0.008
	L_{eq} (dBA)	1	4.031	0.046	0.026
	Proximity	3	2.693	0.048	0.050
	Site	1	2.304	0.131	0.015
	Year(site)	2	2.313	0.102 [a]	0.029
	Sequence(year(site))	5	4.193	0.001	0.121

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity of overflight to sheep; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) date sequence nested within year nested within study site.

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.



* All observed close overflight events occurred between May and August.

Figure 3.10. Mean (+SE) proportion of Dall's sheep active during scan sampling during military jet overflights grouped by proximity: 1) close = jets lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=20 for lamb model); 2) moderate = jets lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=38 for ewe model and *n*=27 for lamb model); 3) far = jets higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=317 for ewe model and *n*=199 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

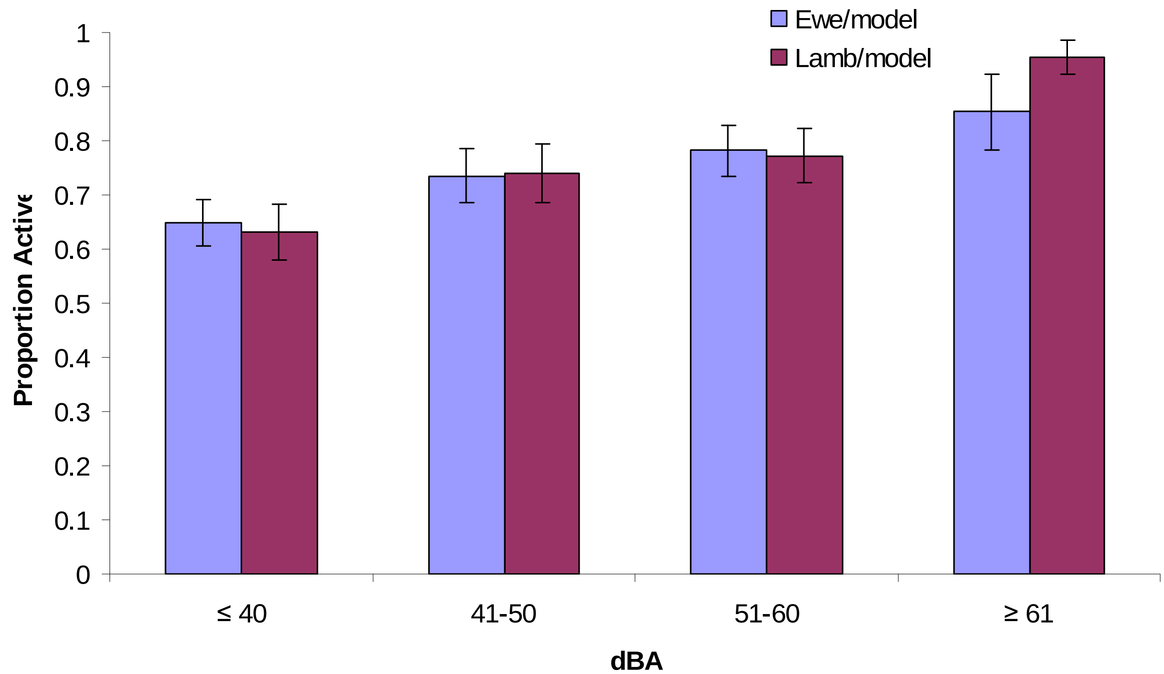


Figure 3.11. Mean (+SE) proportion of Dall's sheep active during scan sampling during military jet overflights grouped by 2 minute mean L_{eq} (dBA): 1) $\leq$ 40 dBA (*n*=90 for ewe model and *n*=65 for lamb model); 2) 41 – 50 dBA (*n*=60 for ewe model and *n*=48 for lamb model); 3) 51 – 60 dBA (*n*=56 for ewe model and *n*=45 for lamb model); and 4) $\geq$ 61 dBA (*n*=20 for ewe model and *n*=13 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

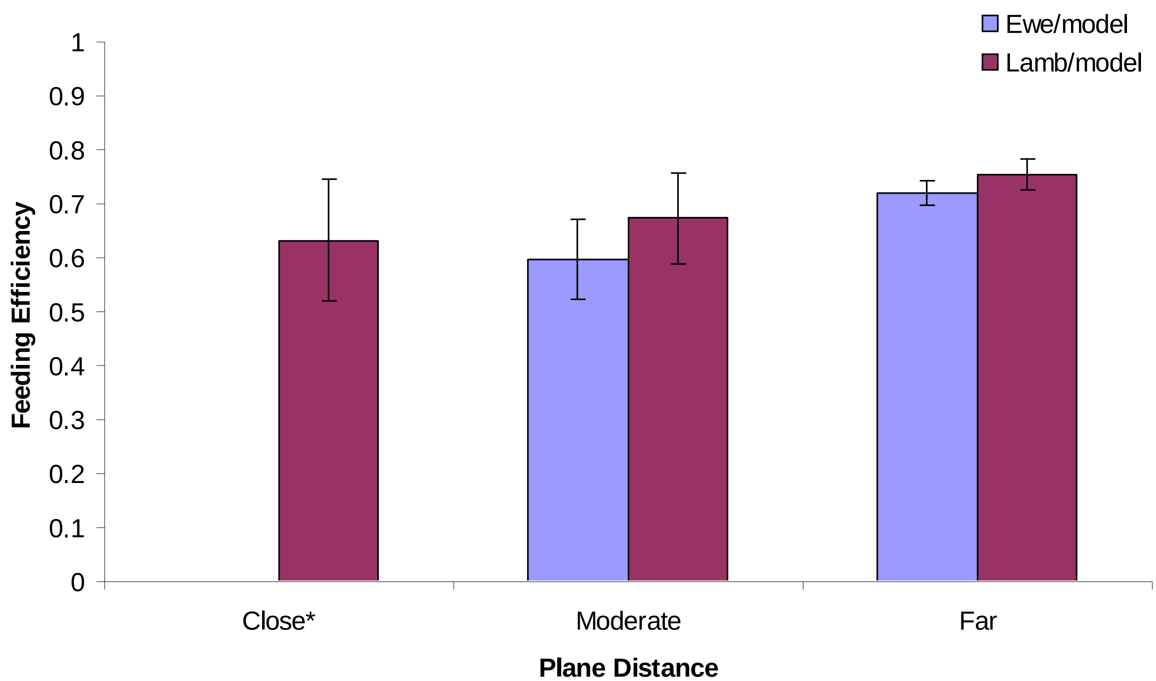
Dall's sheep feeding efficiency was significantly affected by date sequence in the ewe/sound model (Table 3.13). In the lamb/sound model, feeding efficiency declined with increasing numbers of lambs in the group. When 2 minute mean L_{eq} sound levels from overflight events were $\geq$ 61 dBA, feeding efficiency tended to decline in comparison to quieter overflight events but this result was not statistically significant (Fig. 3.11). Feeding efficiency in both the ewe/sound model and the lamb/sound model tended to decline as military jet overflight got closer but again, this was not significant (Fig. 3.12). Independent variables entered into the ewe/sound and lamb/sound models explained 23% and 22% of the variation in feeding efficiency of Dall's sheep. Date sequence accounted for the greatest amount of variation in the ewe model (15%) and the number of lambs in the group accounted for the most variation in the lamb model (8%; Table 3.14) in the feeding efficiency of Dall's sheep when compared to the other independent variables in the models. In the ewe/sound model, year interacted with the covariates (rock, ewe, L_{eq} [dBA]).

Table 3.13. Summary of ANCOVA results examining factors affecting the feeding efficiency of Dall's sheep including proximity and sound level (2 min. mean L_{eq} [dBA]) of military overflights during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent variable*	*d.f.*	*F*	*P*	Partial eta squared
Feeding Efficiency (ewe/sound model)	Rock	1	0.427	0.515	0.003
	Ewe	1	0.023	0.879	0.000
	L_{eq} (dBA)	1	2.847	0.094	0.018
	Proximity	3	1.784	0.153	0.033
	Site	1	3.438	0.066	0.022
	Year(site)	2	0.400	0.671 [a]	0.005
	Sequence(year(site))	11	2.436	0.008	0.147
Feeding Efficiency (lamb/sound model)	Rock	1	0.064	0.801	0.001
	Ewe	1	0.344	0.559	0.003
	Lamb	1	9.693	0.002	0.075
	L_{eq} (dBA)	1	0.804	0.372	0.007
	Proximity	3	1.000	0.395	0.024
	Site	1	0.064	0.800	0.001
	Year(site)	2	2.919	0.058	0.046
	Sequence(year(site))	5	1.727	0.133	0.067

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity of overflight to sheep; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) date sequence nested within year nested within study site.

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.



* All observed close overflight events occurred between May and August.

Figure 3.12. Mean (±SE) feeding efficiency of Dall's sheep during scan sampling during military jet overflights grouped by proximity: 1) close = jets lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=17 for lamb model); 2) moderate = jets lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=32 for ewe model and *n*=21 for lamb model); 3) far = jets higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=256 for ewe model and *n*=141 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

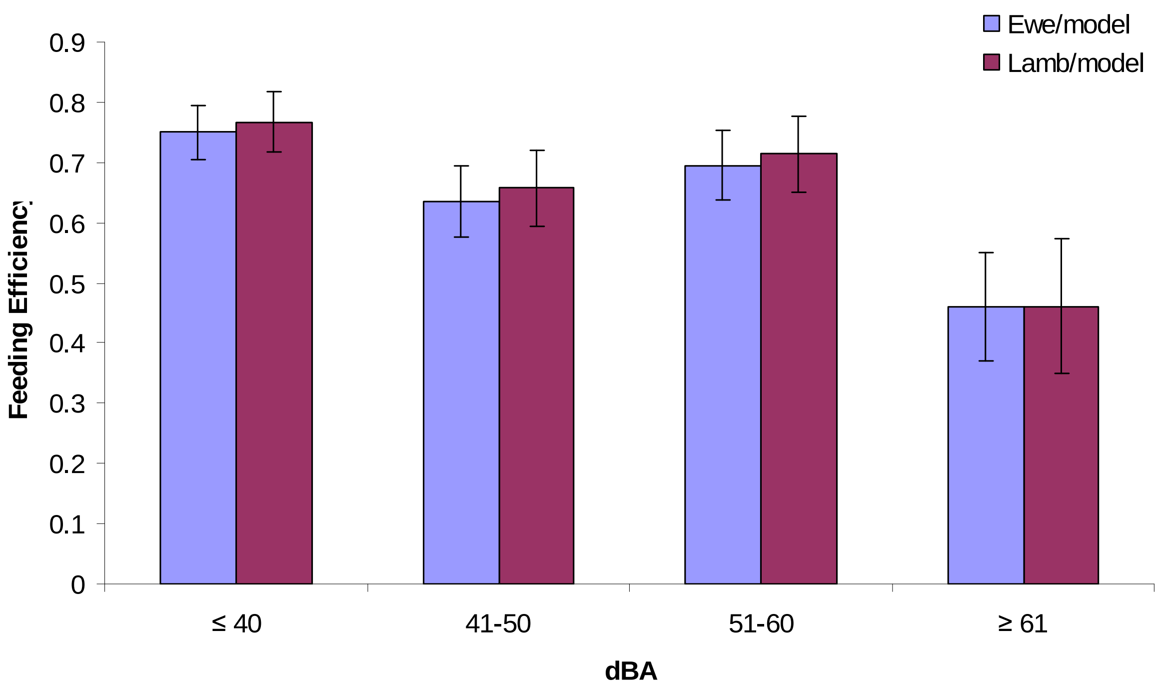


Figure 3.13. Mean (+SE) feeding efficiency of Dall's sheep during scan sampling during military jet overflights grouped by 2 minute mean L_{eq} (dBA): 1) ≤ 40 dBA (*n*=68 for ewe model and *n*=49 for lamb model); 2) 41 – 50 dBA (*n*=46 for ewe model and *n*=37 for lamb model); 3) 51 – 60 dBA (*n*=47 for ewe model and *n*=38 for lamb model); and 4) ≥ 61 dBA (*n*=17 for ewe model and *n*=13 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

There were significant differences in behavior of Dall's sheep associated with the sound level (2 minute mean L_{eq} [dBA]) and the date sequence in the ewe/sound MANCOVA model (Table 3.14). Fewer sheep were bedded (*P*= 0.012) and more sheep were standing (*P*=0.028) with increasing sound levels in the ewe/sound model. There were significant differences in the proportion of animals observed bedding (*P*< 0.001), standing (*P*= 0.002) and feeding (*P*= 0.027) associated with date sequence in the ewe/sound model. Although significant differences occurred in behavior categories across date sequences, no chronological pattern was obvious (Fig. 3.6).

In the lamb/sound MANCOVA model, there was a significant difference in the behavior of Dall's sheep associated with the number of lambs in the group (Table 3.14). A greater proportion of animals were standing (*P*= 0.005) as the number of lambs in groups increased. In addition, a smaller proportion of sheep were observed feeding as the number of lambs in the group increased (*P*= 0.003) in the lamb/sound MANCOVA models. Significant differences in behavior occurred due to the proximity of military jet overflights in the lamb/sound models. Significant differences were detected in the proportion of sheep bedded (*P*=0.048) and walking (*P*=0.020; Table 3.15). As military jets got closer, sheep tended to be bedded less often and walking more often in the lamb/sound model (Fig. 3.14) and although not statistically significant, this pattern was also present in the ewe/sound model. In both the ewe/sound model and the lamb/sound model, sheep tended to walk more as military overflights got louder but these results were not statistically significant. (Fig. 3.15).

Year interacted with the covariates (rock, ewe, L_{eq} [dBA]) in the ewe/sound model (Table 3.14).

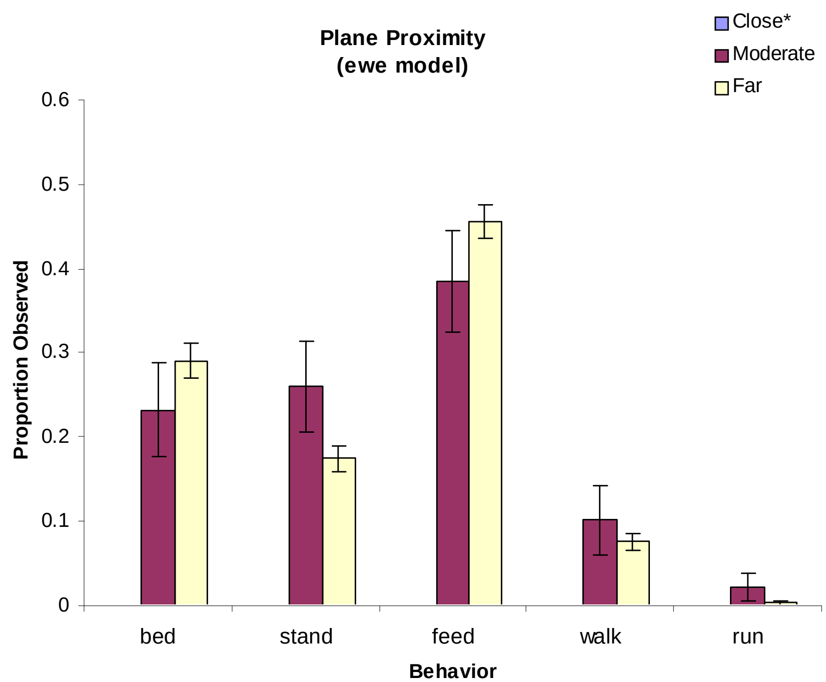
Date sequence explained the most variation in behavior of Dall's sheep in the ewe/sound MANCOVA model (11%) and the number of lambs in the group explained the most variation in the lamb/sound MANCOVA model (8%). Total variation explained by the independent variables in the ewe/sound and lamb/sound MANCOVA models was 28% and 35%, respectively (Table 3.14).

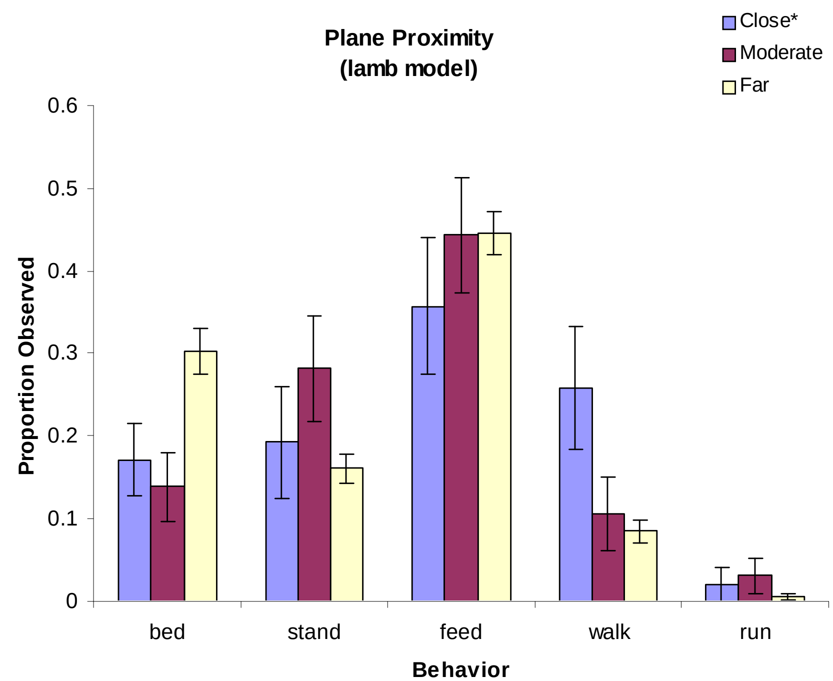
Table 3.14. Summary of MANCOVA results examining factors affecting the behavior of Dall's sheep (percent bedded, standing, feeding, walking, and running) including proximity and sound level (2 min. mean L_{eq} [dBA]) of military overflights during 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs and a second model (restricted to May - July) included lambs in the analysis. Observations were made at 2 sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent Variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Behavior (ewe/sound model)	Rock	4	1.878	0.116	0.036
	Ewe	4	0.170	0.953	0.003
	L_{eq} (dBA)	4	2.423	0.050	0.046
	Proximity	12	1.750	0.054	0.034
	Site	4	1.092	0.362	0.021
	Year(site)	8	1.464	0.169 [a]	0.029
	Sequence(year(site))	44	2.162	0.000	0.106
Behavior (lamb/sound model)	Rock	4	1.689	0.155	0.043
	Ewe	4	0.559	0.693	0.015
	Lamb	4	3.391	0.011	0.083
	L_{eq} (dBA)	4	1.550	0.191	0.040
	Proximity	12	1.845	0.040	0.047
	Site	4	0.974	0.424	0.025
	Year(site)	8	1.759	0.085 [a]	0.045
	Sequence(year(site))	20	1.546	0.052	0.050

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity of overflight to sheep; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) date sequence nested within year nested within study site.

[a] A covariate effect was inferred if the significance of a class effect was different when comparing Type I and Type III Sums of Squares.





* All observed close overflight events occurred between May and August.

Figure 3.14. Mean (+SE) behavior of Dall's sheep during scan sampling during military jet overflights grouped by proximity: 1) close = jets lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=20 for lamb model); 2) moderate = jets lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=38 for ewe model and *n*=27 for lamb model); 3) far = jets higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=317 for ewe model and *n*=199 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

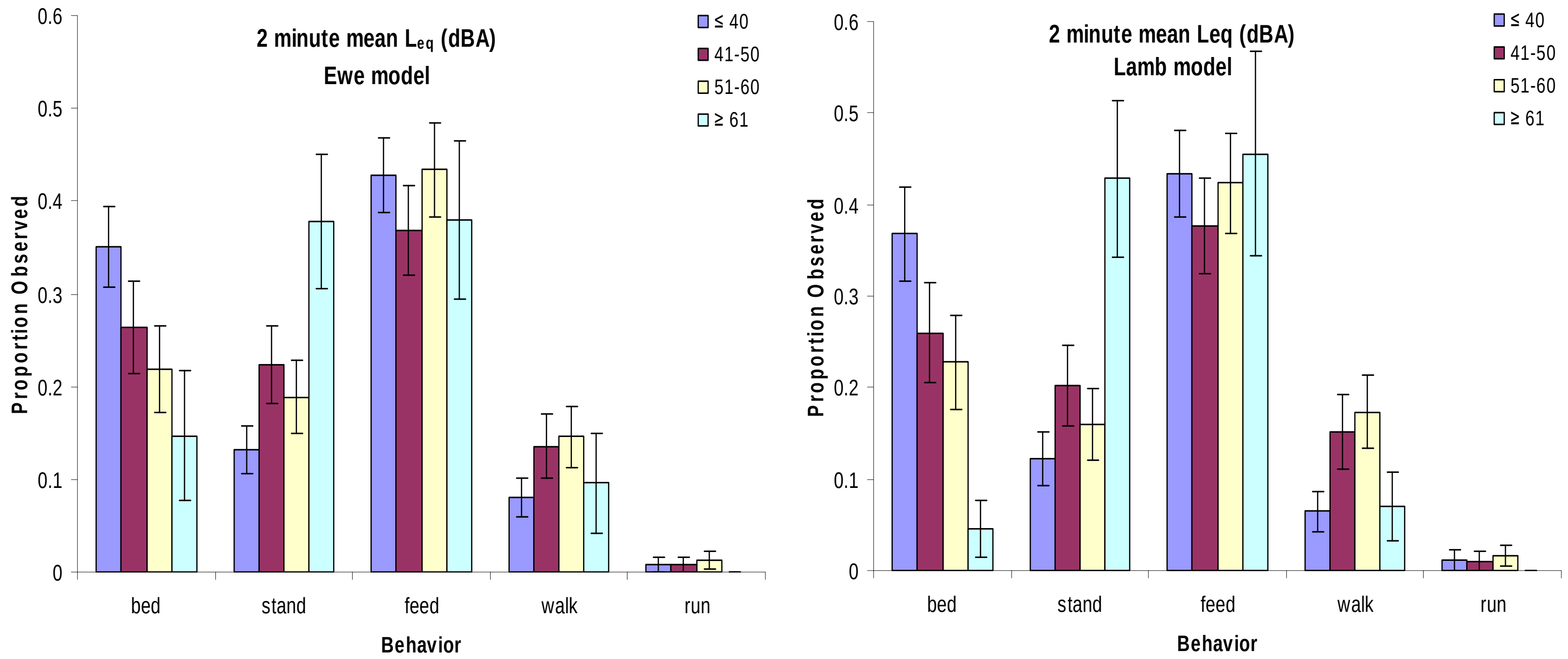


Figure 3.15. Mean (±SE) behavior of Dall's sheep during scan sampling during military jet overflights grouped by 2 minute mean L_{eq} (dBA): 1) ≤ 40 dBA (*n*=90 for ewe model and *n*=65 for lamb model); 2) 41 – 50 dBA (*n*=60 for ewe model and *n*=48 for lamb model); 3) 51 – 60 dBA (*n*=56 for ewe model and *n*=45 for lamb model); and 4) ≥ 61 dBA (*n*=20 for ewe model and *n*=13 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

DISCUSSION

Overflight actvity

Based on 2 field seasons of observation, and attempted observations in a third (1999) military overflight activity in interior Alaska was extremely variable between years, seasons and study areas. We were not able to evaluate the impacts on Dall's sheep of a typical MOA flying schedule as presented in the Final Environmental Impact Statement, Alaska Military Operations Areas (Department of the Air Force 1995) because of the Balkan war (1999), Cope Thunder schedule changes (2000 and 2001), and construction projects (2000). Based on military flying schedules during 2002 and 2003, this uncertainty and fluctuation in the number and extent of military aircraft activity in the MOAs is normal. Therefore, this variability needs to be considered when evaluating mitigation measures designed to reduce potential impacts of military overflights on wildlife species as well as when interpreting the results of this study.

We assumed that the number of observed military overflights would be greater at the West Point study site in comparison to the Cirque Lake study site based on the presence of a mitigation measure at Cirque Lake, the closer proximity of West Point to bombing ranges and Eielson Air Force Base, and personal communication with a individuals familiar with the study areas (Skip Ambrose, National Park Service, personal communication). This assumption was not supported thereby eliminating our ability to compare overall differences in behavior between 2 sites receiving different levels of long-term military overflight activity. In addition, we did not find any statistical differences in the number of military overflights observed during Cope Thunder exercises in comparison to routine flying days. Therefore, it would be difficult to assume that any differences in Dall's sheep behavior observed between Cope Thunder and routine flying days were a product of differences in exposure to military aircraft.

During the mitigation time period (10 May – 15 June), there were no statistical differences in the number of military overflights observed at the two sites suggesting that the reduction in airspace (1,500 m floor in a 7-nautical mile radius circle) did not reduce the air traffic in this area. The altitude restriction also did not eliminate loud overflights from the Cirque Lake Study area. One of the loudest overflight events we experienced (95 dBA) was measured at the mitigated site during the mitigated time period (14 May 2001). Four additional overflights over 80 dBA were measured at the same site on that day.

In general, loud or low military overflight events were rare during our 600 hours of Dall's sheep observation. This was analytically undesirable as small samples sizes could adversely affect statistical power when examining behavior of Dall's sheep exposed to loud or low aircraft. From a management perspective, however, this was a positive condition as exposure of an individual sheep in interior Alaska MOAs to loud and low aircraft is uncommon under the level of military overflight activity we observed in 2000 and 2001. It does, however, raise the question of the potential for sheep in the MOA structure to habituate to military aircraft. Startle and panic behavior occur in most wildlife species evaluated at noise levels greater than 95 dB (Dept. of the Air Force 1992). We observed overflight events $\geq$95 dB during this study in six situations. In these six situations, most Dall's sheep exhibited behavior that may be considered disturbed (standing without feeding, walking and running).

Dall's sheep, therefore do apparently react to loud overflights. Alternatively, interior Alaska MOA airspace originated in 1976. Over the 28 years of the existence of this airspace, multiple generations of Dall's sheep have been exposed to military aircraft overflights and the sheep currently living underneath the MOA airspace have been exposed to military aircraft activity their entire lives. This long exposure without direct consequences associated with the sight or sound of military jet aircraft may have allowed Dall's sheep to habituate to overflights by military aircraft. Habituation to military aircraft activity has been suggested in other populations of wild sheep (Weisenberger 1996, Krausman et al. 1998).

To summarize military overflight activity in interior Alaska MOAs during 2000 and 2001, we observed considerable variation in military overflight activity both temporally and spatially. Differences in aircraft activity associated with Cope Thunders, routine flying days, and mitigated airspace did not necessarily result in differences in exposure to military aircraft by observers on the ground. In those instances when Dall's sheep ewes were exposed to very loud overflight events (>95dBA) Dall's sheep apparently reacted. However, low and loud military jet overflights were rare events. The long exposure of Dall's sheep to military jet overflights in interior Alaska MOAs may have habituated sheep to military overflights thereby minimizing potential negative behavioral responses.

Dall's sheep behavior in relation to military jet overflights

During the 2000 and 2001 field seasons, variables other than military overflights explained more variation in the proportion of Dall's sheep active, the feeding efficiency of Dall's sheep, and the activity budgets of Dall's sheep (Table 3.15). Interactions between some of these variables make interpretation difficult in some instances but some patterns are clear. Date sequence (nested within year and study site) was the most notable of all the independent variables as it was significant in 15 out of 18 models we examined and also tended to explain the most variation in the proportion of Dall's sheep active, the feeding efficiency of Dall's sheep, and the activity budgets of Dall's sheep. The year (nested within study site) was significant in explaining variation in the proportion of sheep active and the activity budget in 6 out of 12 models. The number of lambs and the number of ewes in the group were significant in explaining variation in feeding efficiency and the activity budget of Dall's sheep in 6 out of 6, and 5 out of 12 models, respectively. In lamb models, the distance sheep were from rock was significant in explaining variation in the proportion of sheep active, feeding efficiency and the activity budget in 4 out of 9 models.

The number of overflight we observed over Dall's sheep on a given day was not found to influence Dall's sheep behavior. However, significant differences occurred in the feeding efficiency of Dall's sheep when behavior was examined in the 10 minutes before, during and 10 minutes after an overflight event. Feeding efficiency declined approximately 7.5% during an overflight, then increased approximately 10% by 10 minutes after an overflight. Thus, recovery was quick. Proximity and sound level of overflight events also influenced the proportion sheep active and the activity budget of Dall's sheep (Table 3.15). As sound levels increased, sheep transitioned from bedded to standing (Fig. 3.15) but the response to overflight proximity was complex (Fig. 3.14).

Table 3.15. Summary of significant statistical results from examining factors that may have affected behavior of Dall's sheep during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Behavior	Independent Factor	Overflight metric					
		Observed overflight		Event[a]		Overflight Character[b]	
		Ewe[c]	Lamb[c]	Ewe[c]	Lamb[c]	Ewe[c]	Lamb[c]
Proportion of sheep active	Rock	*	*				*
	Ewe	*					
	Lamb	na		na		na	
	Site						
	Year(site)	*	*	*	*		
	Sequence(year(site))	*	*	*	*	*	*
	Overflight					2*	1*,2*
Feeding Efficiency	Rock	*	*				
	Ewe	*	*				
	Lamb	na	*	na	*	na	*
	Site	*					
	Year(site)						
	Sequence(year(site))	*	*	*		*	
	Overflight			*	*		
Activity Budget	Rock		*				
	Ewe	*		*	*		
	Lamb	na	*	na	*	na	*
	Site	*					
	Year(site)	*	*				
	Sequence(year(site))	*	*	*	*	*	
	Overflight					2*	2*

* Significant result.

[a] Event is a categorical variable: 1) within 10 minutes before an overflight event; 2) during an overflight event, and; 3) 10 minutes after the event.

[b] Overflight were characterized by: #1) proximity (close, moderate or far), and; #2 sound level (2 min. mean L_{eq}).

[c] Ewe = ewe model (data from February – July). Lamb = lamb model (a subset of data from the ewe model spanning the months May – July).

SUMMARY

The number of military overflights that we observed flying over Dall's sheep during 2 field seasons did not significantly affect the proportion of sheep active, the feeding efficiency or the activity budgets of observed sheep.

Dall's sheep feeding efficiency was significantly higher 10 minutes following the overflight event than in the 10 minutes before the event in models that considered only ewes and in models that included lambs. Feeding efficiency is a function of feeding and standing. To lower feeding efficiency, Dall's sheep would need to increase standing relative to feeding. If time spent standing is a relative indication of vigilance, Dall's sheep ewes were less vigilant 10 minutes following the overflight event than before, the opposite pattern of what one would expect if military overflights were disturbing sheep.

Little of the variation in feeding efficiency could be attributed to the before, during or after overflight variable (3% in both models). Although small, feeding efficiency was lower during overflight events in comparison to the before and after feeding efficiencies in both the ewe model and in the lamb model. In the lamb model, this decline in efficiency was statistically significant. This decline in feeding efficiency is an important finding because, by far, most overflights we observed over Dall's sheep were high and far away. We found evidence that Dall's sheep react more strongly to close and loud jets than to quiet jets far away. Therefore, an increase in the frequency of low overflights over Dall's sheep could further reduce feeding efficiency during the overflight event. The duration of this impact, however, may be short lived based on the high, 10 minute post military overflight event feeding efficiency. Behavioral responses of short duration are consistent with those from other studies investigating the impacts of military overflights on wildlife. Magoun et al. (2004) Murphy et al. (1993) and Harrington and Veitch (1991) found that overt behavioral responses by caribou to overflights were short-term. Weisenberger et al. (1996) and Krausman et al. (1998) found few behavioral changes when comparing activity of bighorn sheep before an overflight event to 3 minutes after the overflight event. Heart rate data supports the conclusion that responses to military overflights are short lived (Weisenberger et al. 1996, Krausman et al. 1998).

The proportion of Dall's sheep active during an overflight event increased as military jets got closer (Fig. 3.10) and louder (Fig. 3.11). The variables of sound level and jet proximity explained 5% and 8% of the variation in the proportion of animals active in the ewe model and lamb model respectively. Sheep bedded less and stood more in the ewe model as the sound of an overflight increased, and in the lamb model, sheep bedded less and walked more when jets were closer. Military aircraft overflights can therefore exert an energetic cost on Dall's sheep. The magnitude and biological significance of this cost however would depend on the sound level produced by the overflights, the proximity of the overflights, the frequency of exposure to overflights, and the nutritional status of the animal as well as the interactions of these variables.

CHAPTER 4: Daily Movements, Home Range Size and Habitat Use by Dall's Sheep in Relation to Study Area, Year, Season and Military Aircraft Sorties

INTRODUCTION

The startle response of sheep (Krausman and Hervert 1983, Krausman et al. 1998) to high speed military overflights could affect the daily movements, subsequent home range size, and habitat use by sheep. Daily movement might increase if sheep attempted to escape from aircraft disturbance, or movement might decrease if sheep sought out and remained in areas that offered security from disturbance. Home range size might be expected to respond in a similar manner. If daily movements and/or home range area changed substantially as a result of overflights, then changes in habitat use might be expected as well.

Estimating the magnitude and statistical and biological significance of any potential overflight effect is difficult when there is substantial variability in 1) habitats between study areas, 2) annual conditions among years, 3) seasonal conditions within years, and 4) individual sheep. To be deemed statistically significant, sheep response to aircraft activity must be distinguished from natural variance due to habitat, annual and seasonal conditions, and individuals. To be deemed biologically significant, the magnitude of any statistically detectable and/or demonstrated effect must be sufficient to reasonably be expected to affect population performance (e.g. growth, productivity, survival, population size). In both the statistical and biological sense, adequate replication of experimental units (sheep) and treatment levels (i.e. aircraft activity) among classification variables (i.e. study area, year, season within year) is essential for reliable and robust results.

To assess the potential influence of military overflights on sheep behavior and habitat use, we conducted multiple analyses of covariance to estimate whether or not the average number of military flight sorties launched in 2-week periods influenced our estimates of the effect of study area, year within study area, and 2-week period within years within study areas on daily distance moved, home range size, and habitat use of adult female Dall's sheep in two study areas in Military Operation Areas (MOA) 1 and 2, interior Alaska, from late-April through early-August, 1999-2002.

METHODS

In two study areas (Cirque Lakes (CL) and West Point (WP)) during four years (1999-2002) approximately 10 adult female sheep were GPS collared in late winter (~March) and their locations recorded at 3 (1999) or 4 (2000-2002) hour intervals for the ensuing 8 months each year. Collars were removed at the end of the monitoring period and a new sample of sheep was instrumented the following year. Analyses were focused on eight successive 2-week periods that began on ~15 April and continued through ~ 10 August each year. These intervals were mutually exclusive within years, and were keyed to actual/scheduled MFEs in each year. As a result, the beginning/ending dates of the 2-week periods were not constant among years, but starting and ending dates for each successive period varied only by ~3 days among years. The periods were named late-

April, early-May, Late-May, early-June, late-June, early-July, late-July, and early-August and referred to as sequences 3-10, respectively.

Habitat attributes at locations of sheep (landcover class, slope, aspect, elevation, terrain ruggedness, relative green biomass at peak vegetation development (NDVI; Tucker 1979, Tucker et al. 1986) were derived from remotely sensed TM land cover classifications (Ducks Unlimited 1998) and from digital elevation models. The 18 original TM landcover classes were condensed into forest, shrub-grass-herb, and sparsely vegetated types to reduce the occurrence of empty cells.

NDVI indexes the disproportionate reflectance of near-infrared radiation from green vegetation (Tucker and Sellars 1986) in the canopy of plant communities. We obtained NDVI from a TM image taken on 11 July 1994, the only image which we could find that gave near complete cloud-free coverage of both study areas. NDVI was calculated from bands 3 and 4 as NDVI = (Band4 - Band 3)/(Band4 + Band3) and converted to the decimal range 0-1.0 by setting values less than 0 to 0 (Griffith et al 2002). A portion of the western side of the West Point study area was not covered by the NDVI grid and NDVI was set to missing for that area.

Terrain ruggedness (Nicholson et al. 1997) was estimated as the sum of diversity in slope and diversity in aspect within the average 4-hour-movement radius of locations. We used the sum, rather than the product (Nicholson et al. 1997), of diversity in slope and aspect because the product increased the range of estimated ruggedness approximately 10-fold compared to estimates of ruggedness obtained for slope or aspect alone. The sum maintained the proportional range of the original data.

Movement distance was estimated as the sum of straight line distances between successive locations within 2-week sequential period. This constituted a minimum estimate of total distance traveled.

Minimum convex polygon (MCP) home ranges were calculated from locations for each sheep within 2-week periods. A maximum of 90-120 locations was available for each sheep in each period; MCP home range sizes became asymptotic at approximately 50 locations; sheep with less than 50 relocations for the 2-week sequential periods were excluded from analyses. Usually these were sheep that died or sheep with collar failure within a period.

MCP home ranges were used, in contrast to more sophisticated techniques such as least squares cross validated fixed kernels (Seaman et al. 1996, 1998, 1999), to obtain the simplest reasonable estimate of habitat availability and the extent of area used. Although fixed kernel utilization distributions give a better estimate of the intensity of area use than MCPs (Seaman et al. 1998), in this particular case fixed kernel 99% utilization distributions were often fragmented and excluded area that sheep were logically required to have passed through in the 3-4 hours between relocations when moving from one portion of their home ranges to another.

The number of sorties launched each day into MOA1 and MOA2 provided an estimate of area-wide overflight intensity and were obtained from USAF personnel. The CL study area lies entirely with MOA1 while the WP study area is located in both MOA1 and MOA2 (Chapter 3, Fig. 3.1). Because the number of daily sorties in MOA1 was highly correlated with the daily total of sorties in MOA1 and MOA2 combined (r^2=0.97), we used the number of sorties in MOA1 as our estimate of relative intensity of flying on a daily basis for both the CL and WP study areas. For each sheep, we averaged the number of sorties launched for the actual days that a sheep generated GPS locations within each 2-week sequential period.

We assessed the effect of year and sequential 2-week period on the number of sorties launched per day with ANOVA (PROC GLM, SAS V8e Windows).

We used multiple analysis of covariance (MANCOVA; PROC GLM, SAS V8e Windows) to test whether or not the average daily number of sorties in MOA1 within each 2-week period increased the precision of our estimates of the effect of the study area, and the nested effects of years within study areas and sequential periods within years within study areas (class variables) on dependent behavioral variables. The vector of behavioral data included: 1) 2-week MCP home range size (km^2) for each sheep, and 2) sum of daily distances moved (km) within the 2-week home range for each sheep.

We also used the sorties covariate in a separate multiple analysis of covariance of the influence of the class variables on the vector of habitat use within the 2-week home range for each sheep. The vector of habitat use for each sheep was composed of 11 elements that included the proportional use of three landcover classes (timber, grass-shrub-herb, and sparsely vegetated; unknown landcover was used to calculate proportions but excluded from further analysis), proportional use of four aspects (90^o arcs including N, S, E, and W), average elevation, average slope, average terrain ruggedness, and median maximum vegetation greenness (NDVI), all estimated from the 50-120 GPS relocations of each sheep in each 2-week sequential period. Class variables were fixed effects and expected to be significant sources of variation in the dependent variables due to different habitats between study areas, different annual conditions among years, and the natural phenological progression of forage plants and energetic status of sheep across the eight 2-week periods within years. We assessed whether the average number of daily sorties was related to the dependent variables and compared Type I SS and Type III SS for the class effects to estimate whether the number of sorties influenced the significance of class effects. All analyses were conducted twice; once with the covariate entered first and once with the covariate entered last.

There was some multi-collinearity in our data. Sparsely-vegetated areas tended to be less green and at higher elevation and timbered areas tended to be more green and at lower elevation. There were also correlations between East and West aspects, and East aspects tended to have less steep slopes. To assess the influence of multi-collinearity, we deleted landcover class and East aspects from our data, reanalyzed, and compared the conclusions to those reached from consideration of all data.

Overall, 523 observations were available for the behavioral analyses and 567 observations were available for the habitat use analyses. These were distributed within the two-study-area by four-year by eight-2-week-period design for an average of 8-9 sheep per cell. All statistical tests were conducted at the *a priori* α=0.05 level of significance.

We used simulation modeling to assess the power of our analyses to detect significant differences in the multiple analyses of covariance (Appendix F).

RESULTS

Potential influence of military aircraft sorties on behavior and habitat use

There were no differences in conclusions reached due to inclusion/exclusion of correlated independent variables.

From early April – early August, the average number of sorties launched per day was significantly (P < 0.001) different among years (22.9, 12.5, 25.7 and 31.8 sorties/day for 1999-2002, respectively) and among sequential periods within years (P < 0.001; 21.8, 21.3, 12.7, 8.0, 28.7, 12.8, 52.3 and 18.2 sorties/day for sequential periods from late-April through early-August, respectively) (Fig. 4.1). Sorties were at their lowest annual values during and immediately after lambing (late-May and early-June) and were highest in late-July. Spikes in sorties accompanied actual Cope Thunder Military Flying Exercises (MFEs) in early- May, late-June and late-July (Fig. 4.1). The average number of sorties launched per day was significantly greater (P < 0.001) during actual MFEs (59.8) than during periods without MFEs (18.7).

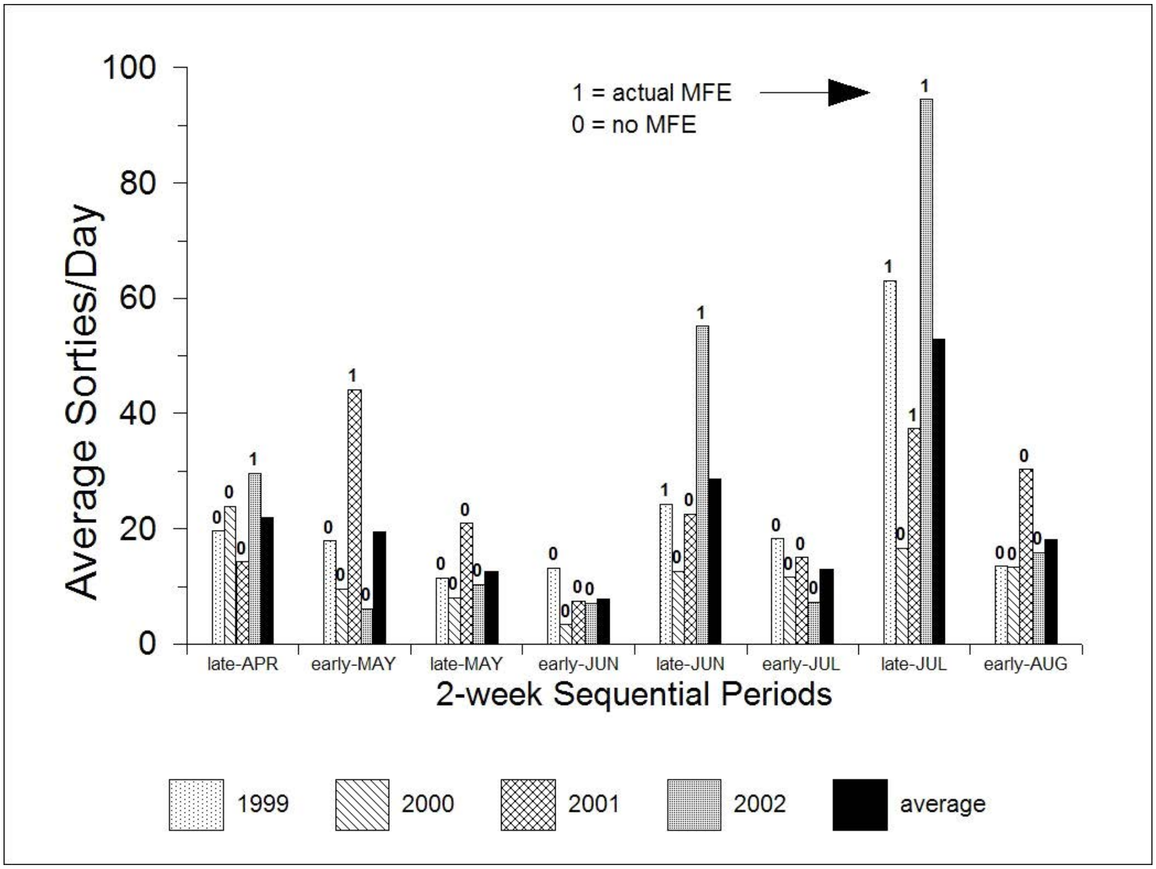


Figure 4.1. Average number of military sorties launched per day into MOA 1, 1999-2002, in eight 2-week sequential periods within years.

There were overall significant ($P < 0.001$) effects of study area, year within study area, and sequential period within years within study areas on home range size and distance moved. The full model explained 42% of the variance in minimum total distance traveled during the 2-week periods and 62% of the variance in 2-week MCP home range size. When considered alone (Type I SS) and entered first in the modeling process, the average number of sorties/day was significant ($P < 0.001$) for both distance moved and home range size. However, the sorties covariate was 1) never significant (distance P = 0.953; home range size P = 0.14) once the effects of study area, year within study area, and sequential period within year within study area were in the model (Type III SS), and 2) did not change the significance of any of the main class effects.

There were overall significant ($P < 0.001$) effects of study area, year within study area, and sequential period within years within study areas on the vector of habitat use (proportional use of landcover classes (3), proportional use of aspects (4), average slope, average elevation, average terrain ruggedness, and median maximum vegetation greenness (NDVI)). The full model explained 27-57% of the variance in individual elements of the habitat use vector. When considered alone (Type I SS) and entered first in the modeling process, the average number of sorties/day was significant ($P < 0.0008$) for proportional use of grass-shrub-herb landcover, proportional use of north and south aspects, and average terrain ruggedness. However, the sorties covariate was never significant ($P > 0.084$) once the effects of study area, year within study area, and sequential period within year within study area were in the model (Type III SS) and never changed the significance of any of the main class effects.

There was a visual suggestion that average home range size (Fig. 4.2), 2-week travel distance (Fig. 4.3) and terrain ruggedness used (Fig. 4.4) may have been increasing from 10 through 30 sorties per day. However, separate analyses of the relationships between the dependent variables and the number of sorties per day within this restricted range did not show a significant ($P > 0.405$) relationship. There was no visual suggestion of a relationship between sortie/day and any other habitat use variable.

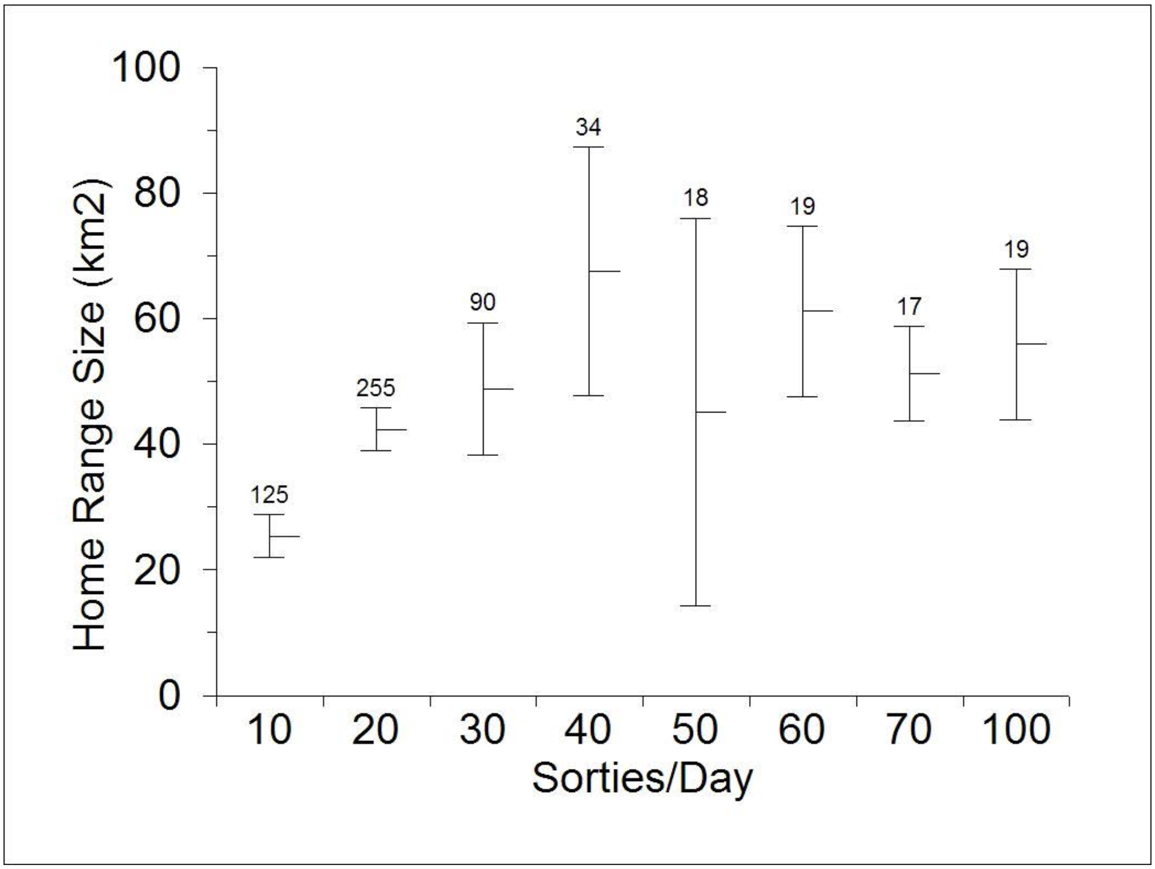


Figure 4.2. Average MCP home range size of sheep in relation to number of military sorties launched per day into MOA 1, interior Alaska, late-April through early-August, 1999-2002. Bars encompass the mean plus or minus 2 standard errors. Labels are the number of sheep*year*sequence combinations that yielded the mean.

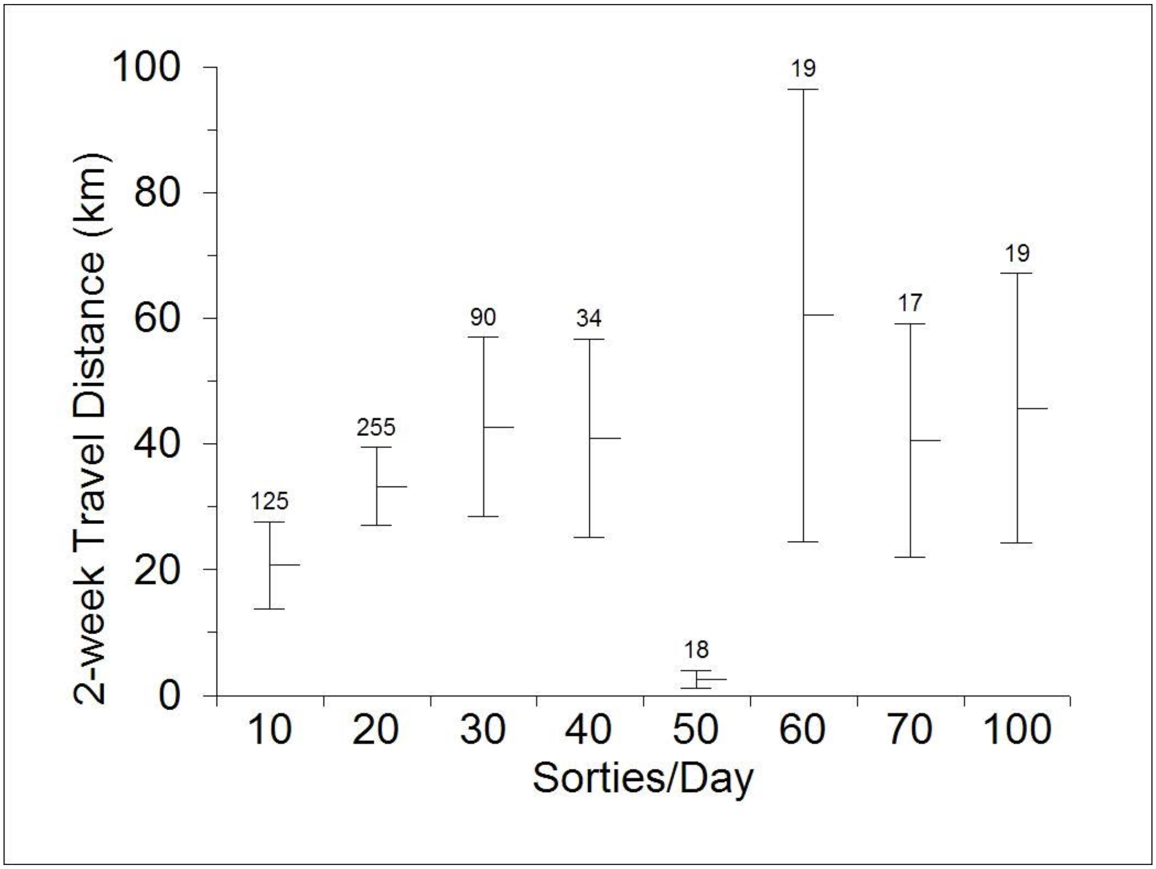


Figure 4.3. Average 2-week minimum total distance traveled by sheep in relation to number of military sorties launched per day into MOA 1, interior Alaska, late-April through early-August, 1999-2002. Bars encompass the mean plus or minus 2 standard errors. Labels are the number of sheep*year*sequence combinations that yielded the mean.

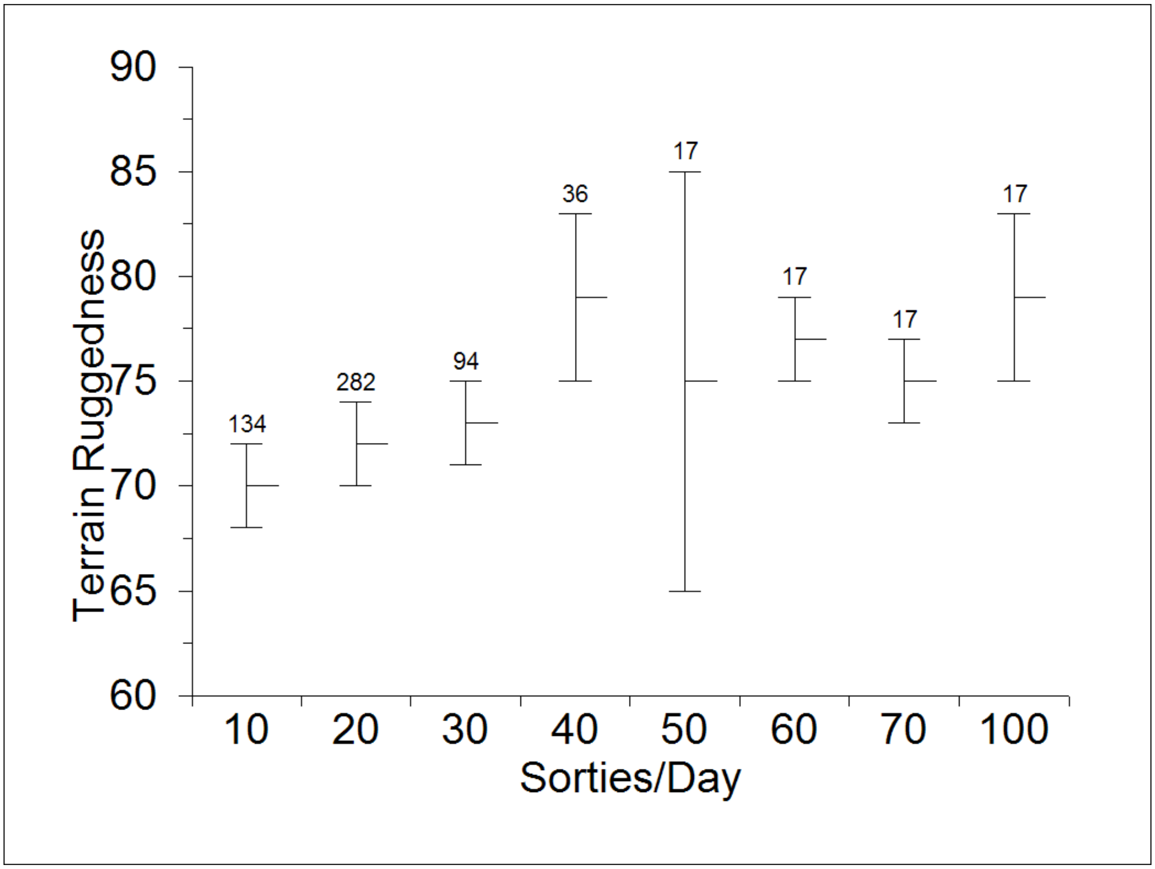


Figure 4.4. Average terrain ruggedness used by sheep in relation to number of military sorties launched per day into MOA 1, interior Alaska, late-April through early-August, 1999-2002. Bars encompass the mean plus or minus 2 standard errors. Labels are the number of sheep*year*sequence combinations that yielded the mean.

Our simulation assessment of the statistical power of our tests (Appendix F) suggested that if the magnitude of mean differences in behavior and habitat use observed in Figures 4.2-4.4 were real, it would have taken a sample size of approximately 20 sheep per study area to declare them statistically significant.

Behavior and habitat use by study area, year and sequence

Average home range size in West Point (47.8 km^2) was significantly ($P < 0.0001$) larger than average home range size in Cirque Lakes (14.0 km^2) and there was significant ($P < 0.0001$) variation in home ranges sizes among years within study areas and among sequential periods within years within study areas at West Point (Fig. 4.5) and Cirque Lakes (Fig. 4.6). Particularly for West Point (Fig. 4.5), home range sizes became quite large in late-June, about a month after lambs were born, and remained large thereafter through early August. Increase in home range size from late-June onward was evident for Cirque Lakes only in 1999.

Average minimum total distance traveled within 2-week sequential periods at West Point (51.3 km) was significantly (*P* < 0.0001) larger than distance traveled at Cirque Lakes (35.8 km) and there was significant (*P* < 0.0001) variation in distance travelled among years within study areas and among sequential periods within years within study areas at West Point (Fig. 4.7) and Cirque Lakes (Fig. 4.8). There was a tendency toward greater travel distance as the seasons progressed in both study areas (Figs. 4.7, 4.8). Total distance traveled was quite high for West Point in 2001 in all periods except early- and late-June (Fig. 4.7), and distance traveled was highest in Cirque Lakes during late-June and early-July of 1999 (Fig. 4.8).

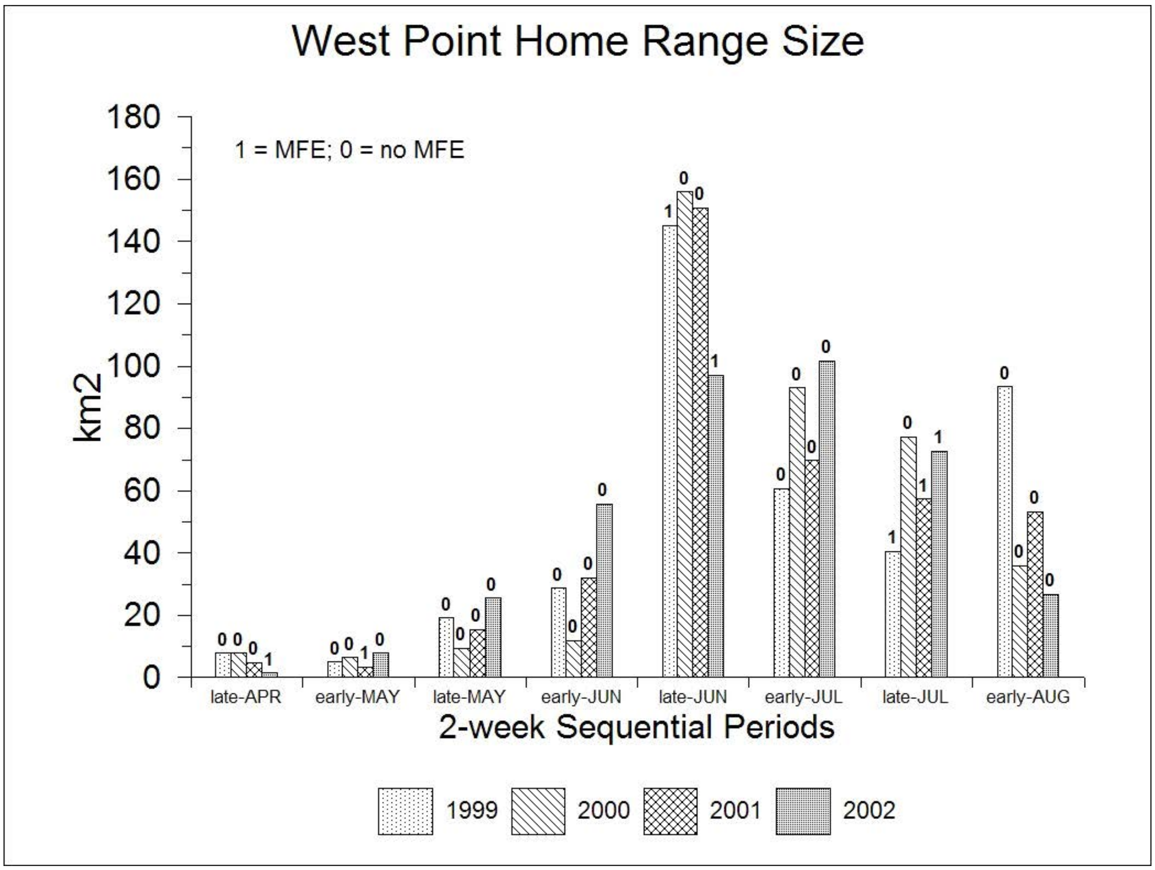


Figure 4.5. Average MCP home range size (km^2) for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

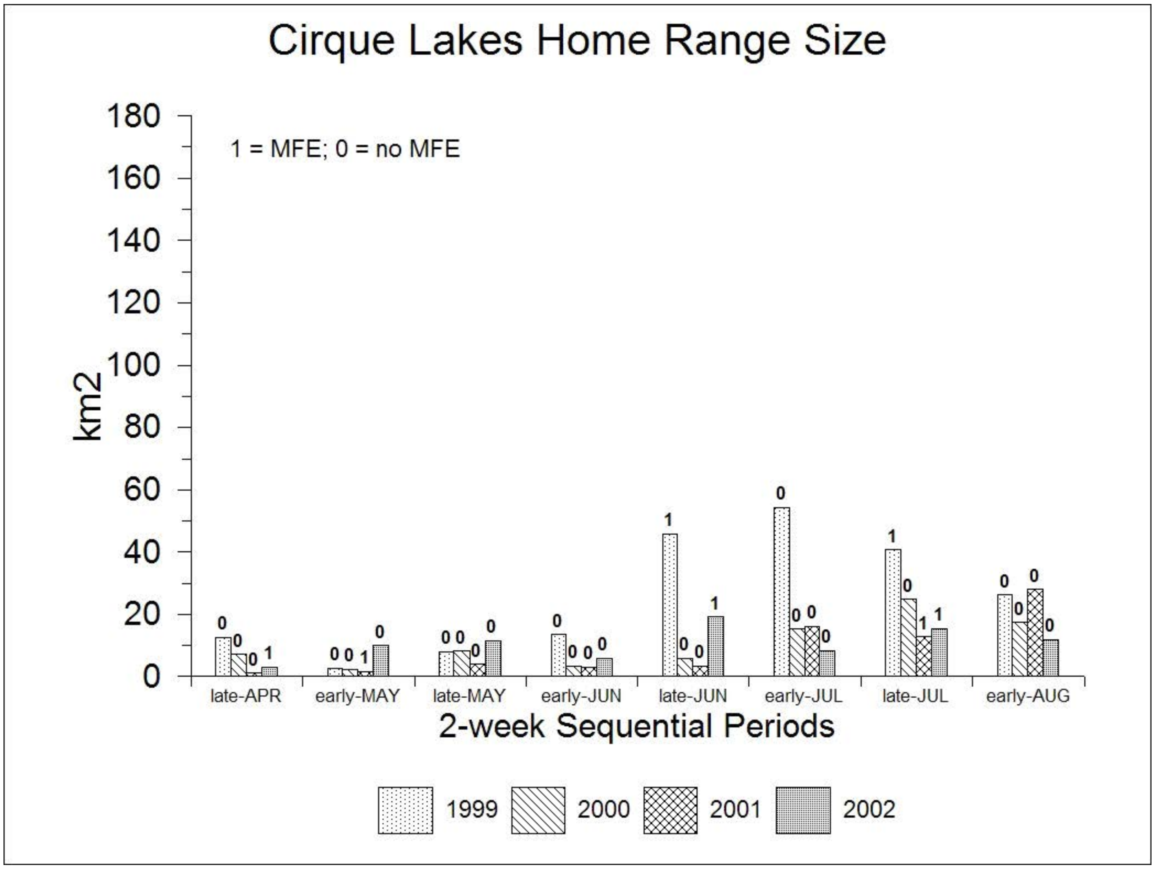


Figure 4.6. Average MCP home range size (km^2) for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

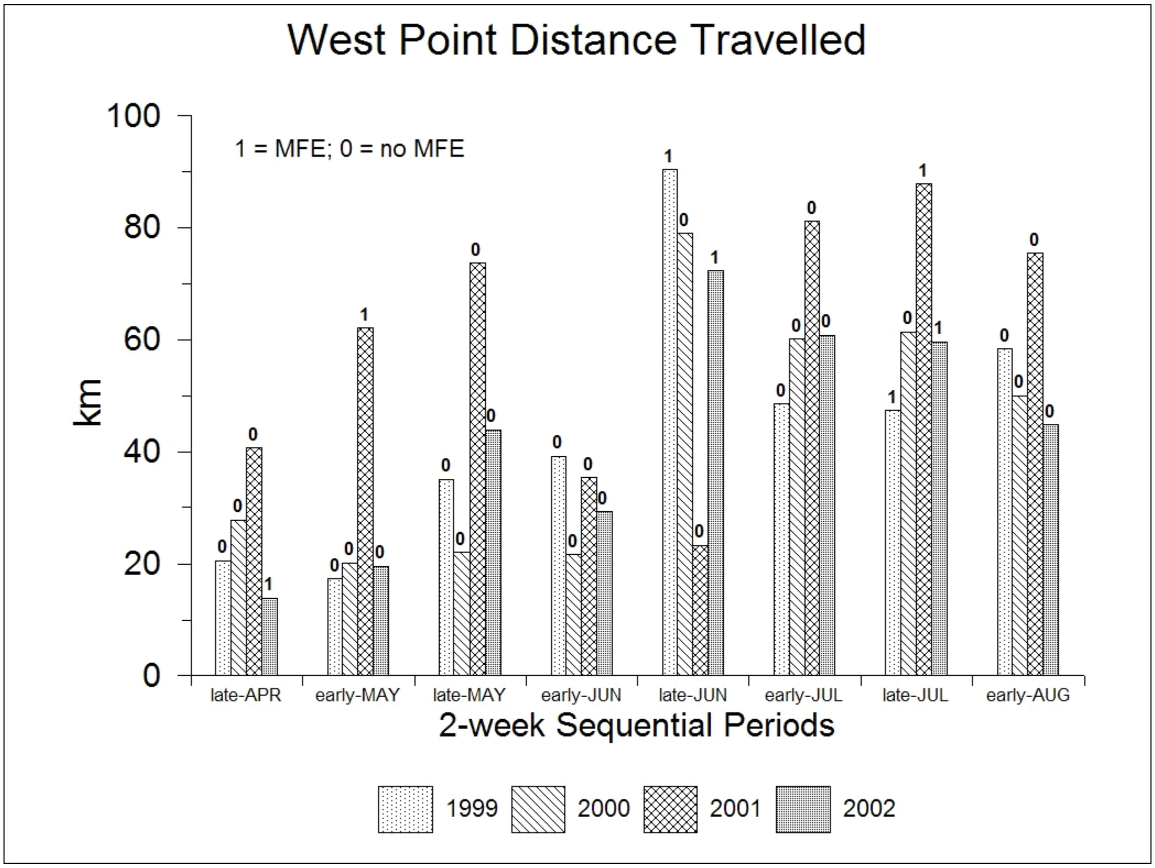


Figure 4.7. Average minimum total distance (km) traveled in 2-week sequential periods for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

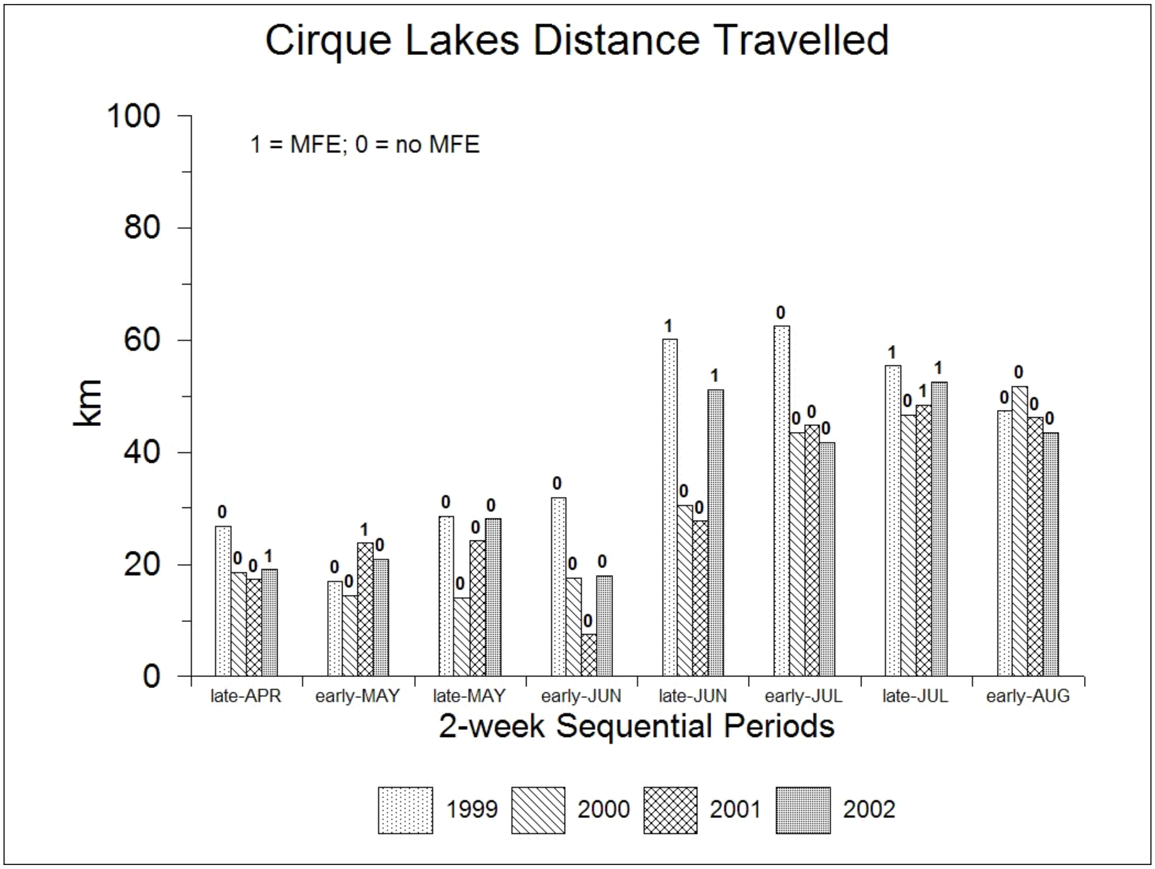


Figure 4.8. Average minimum total distance (km) traveled in 2-week sequential periods for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

In both study areas, use of the sparsely vegetated landcover class accounted for more than half of the usage and there was slightly greater ($P < 0.0001$) proportional use of the sparse landcover class in West Point (0.606) compared to Cirque Lakes (0.539; Figs. 4.9, 4.10). Some exceptions to this were evident for West Point in early-April through early-May in 1999 and late-May through early-June in 2001 (Fig. 4.9) when use of sparsely vegetated areas was reduced well below half of all landcover usage. Sparsely vegetated areas tended to be at higher elevation.

There was significantly ($P < 0.0001$) less proportional use of the timber landcover class in West Point (0.057, Fig. 4.11) compared to Cirque Lakes (0.187, Fig. 4.12). Substantial use of the timber class at Cirque Lakes was particularly evident from early-April through early-July in 2001, and from late-June through early-August in 2002 (Fig. 4.12). Much of the use of timber in Cirque Lakes was associated with sheep making substantial use of the bluffs of the Charley River in those years and sequential periods.

Conversely, there was significantly ($P < 0.0001$) more proportional use of the grass-shrub-herb landcover class in West Point (0.314, Fig. 4.13) compared to Cirque Lakes (0.126, Fig. 4.14). In both study areas, there was a tendency toward increased relative use of the grass-shrub-herb landcover class from early-April through early-June compared to the remainder of the sequential periods (Figs. 4.13, 4.14) but this was not evident in all years.

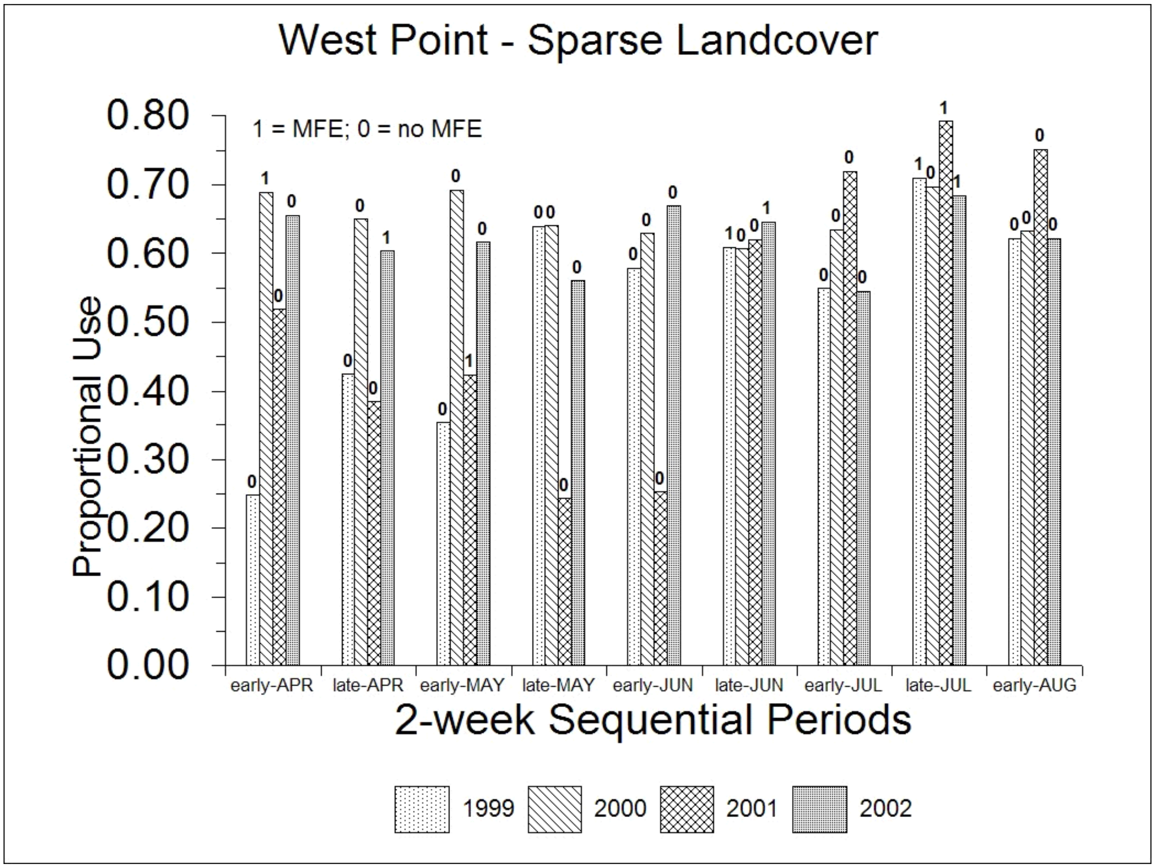


Figure 4.9. Average proportional use of the sparsely vegetated landcover class for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

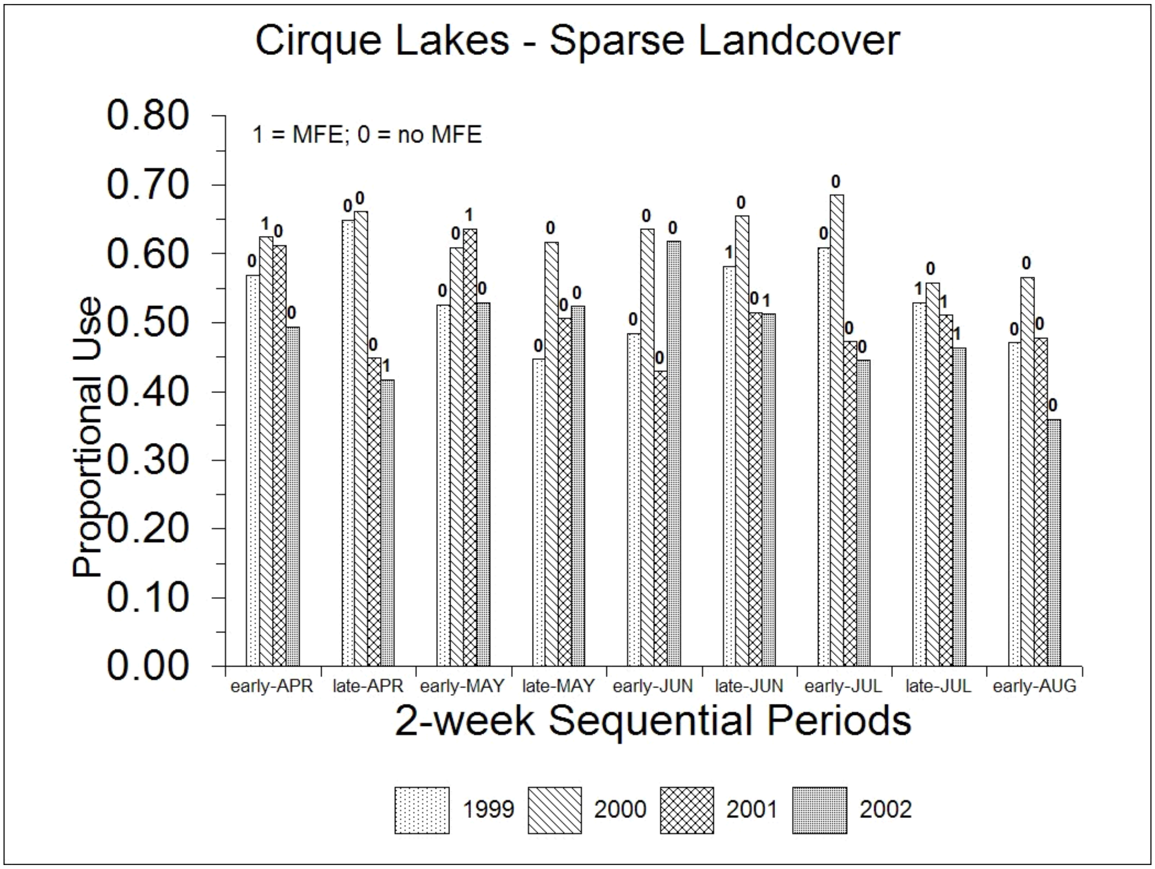


Figure 4.10. Average proportional use of the sparsely vegetated landcover class for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

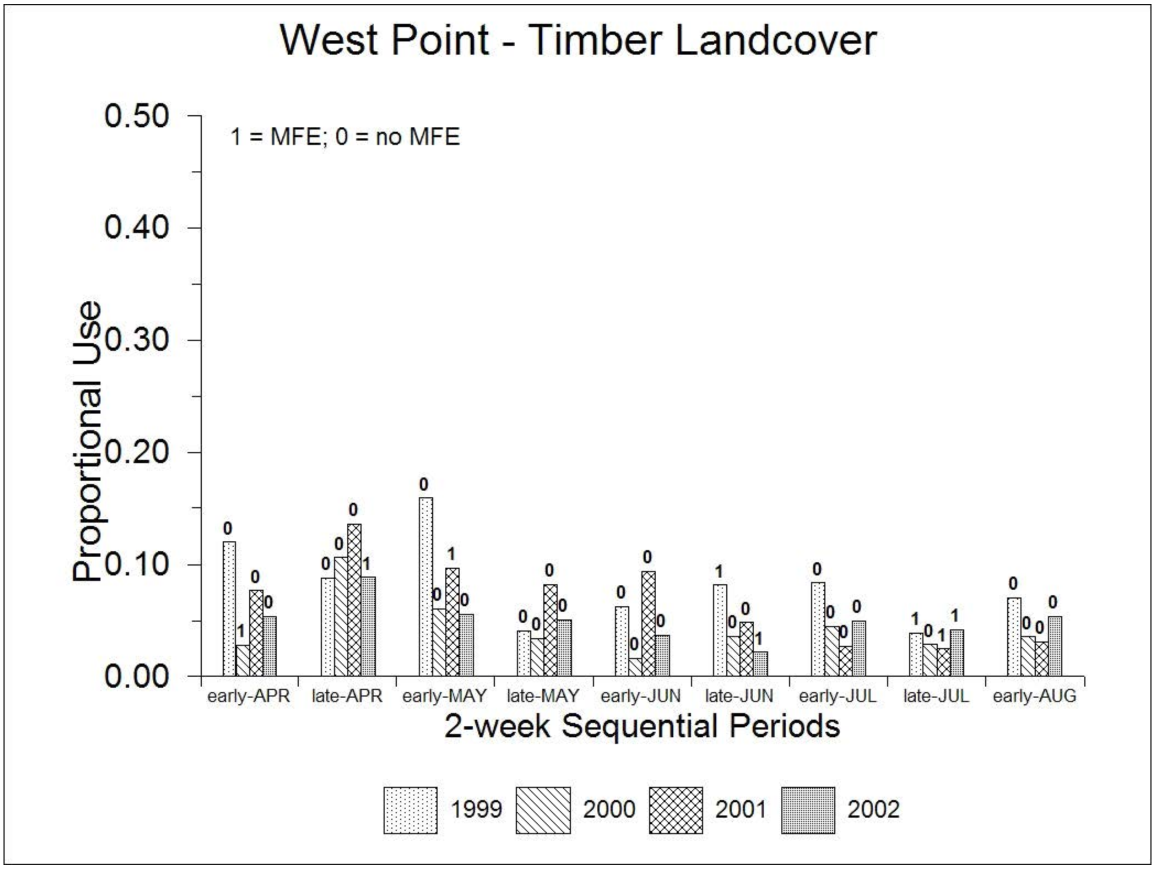


Figure 4.11. Average proportional use of the timber landcover class for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

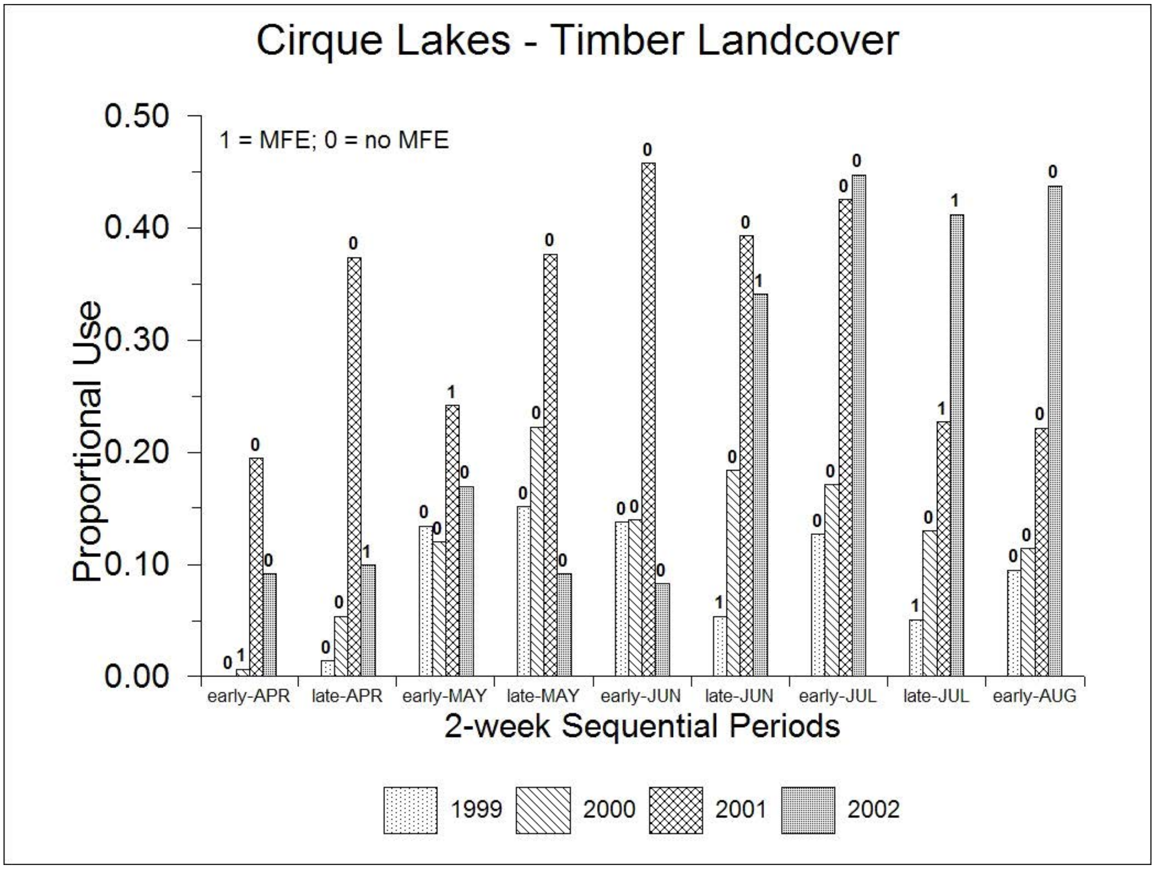


Figure 4.12. Average proportional use of the timber landcover class for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

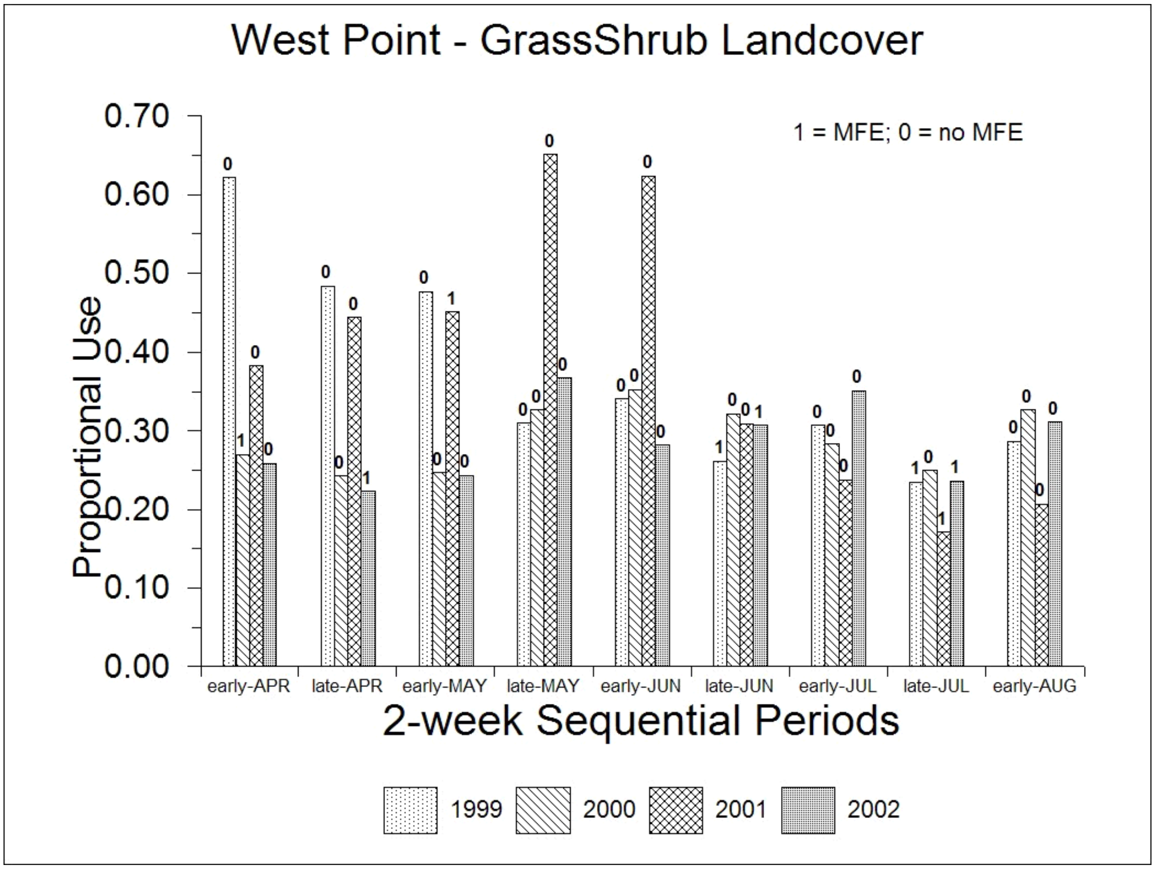


Figure 4.13. Average proportional use of the grass-shrub-herb landcover class for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

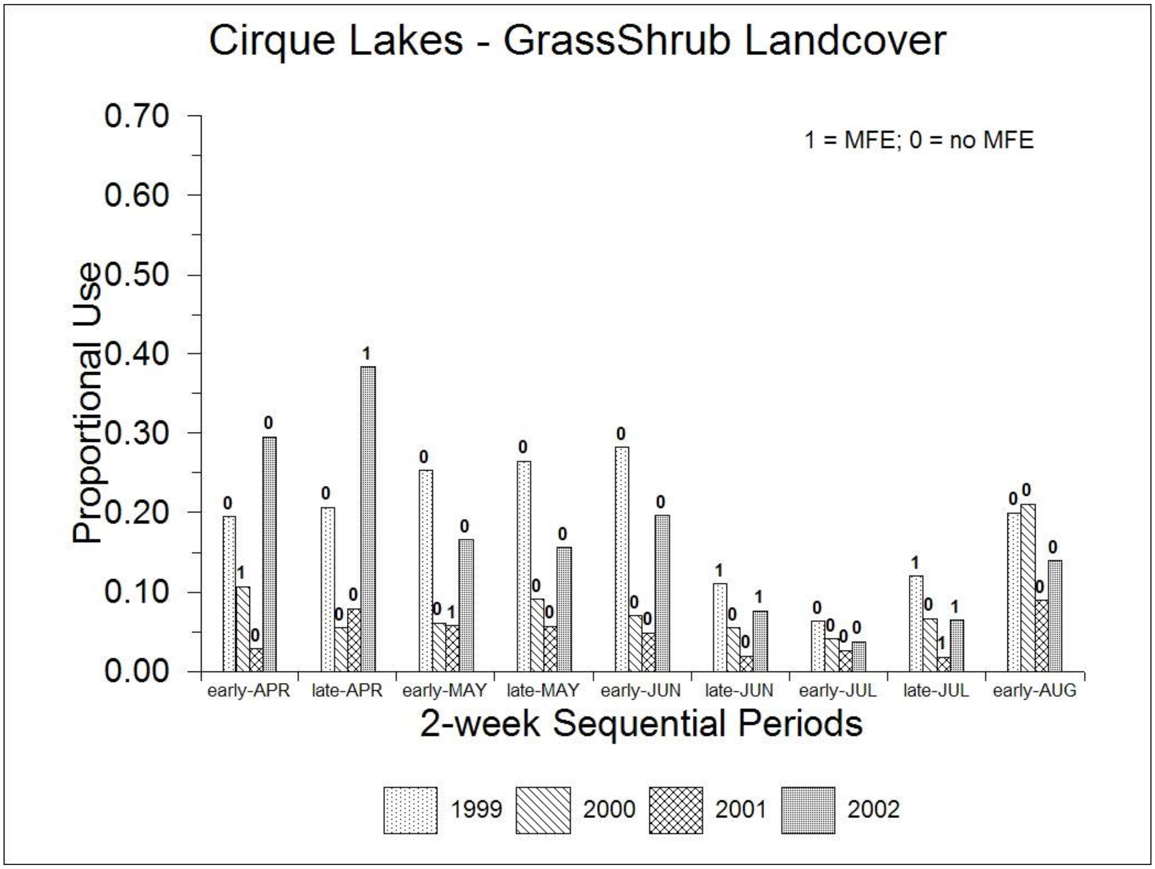


Figure 4.14. Average proportional use of the grass-shrub-herb landcover class for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

From early-April through early-May in 1999 and from early-April through early-June in 2001, sheep at West Point used sites that would ultimately have relatively high plant biomass at peak vegetation development (Fig. 4.15). This pattern of use was coincident with increased use of the grass-shrub-herb landcover class in the same sequential periods and years (Fig. 4.13). The average NDVI at used sites for Cirque Lakes (0.101; Fig. 4.16) was slightly greater ($P < 0.001$) than at West Point (0.079) but this may have been influenced by the greater use of the timber landcover class at Cirque Lakes (Fig. 4.12) compared to West Point (Fig. 4.11). NDVI estimates greenness in the vegetation canopy, and if the canopy is unavailable to sheep (i.e. the tops of trees), it may not indicate greater forage availability.

Proportional use of elevation (Figs. 4.17, 4.19) and slope (Figs. 4.18, 4.20) at West Point was more consistent among years and sequential periods than at Cirque Lakes but, on average, sheep used slightly higher elevations (1,346m vs. 1,195m; $P < 0.0001$) at West

Point compared to Cirque Lakes, and slightly steeper slopes (51.8% vs. 47.1%; *P* <0.0001) at Cirque Lakes compared to West Point, respectively.

At West Point, used terrain was slightly less rugged than at Cirque Lakes (71.3 vs. 75.4, respectively, *P* < 0.0001) and this difference was most pronounced from early-April through early-May (Figs. 4.21, 4.22). Terrain shadow and unknown landcover classes at sheep locations tended to be more prevalent in Cirque Lakes (14.8%) than in West Point (2.9%). This probably reflected steeper and more rugged terrain in Cirque Lakes which would be more likely to be in shadow on a satellite image. Thus, we probably underestimated the difference in use of rugged terrain between Cirque Lakes and West Point.

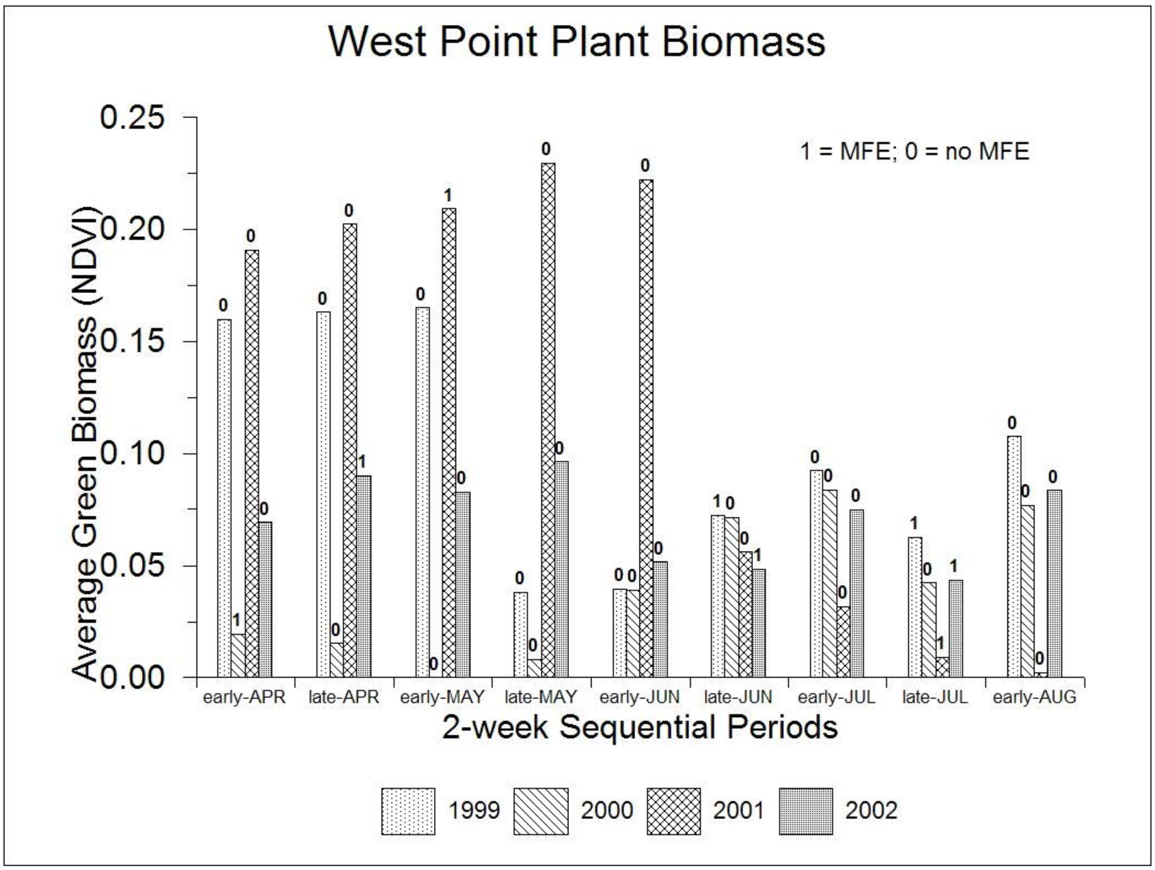


Figure 4.15. Average maximum relative green plant biomass (NDVI) at sites used by Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE). NDVI estimates obtained from a single TM image from 11 July 1994 near the peak of vegetation development for that year.

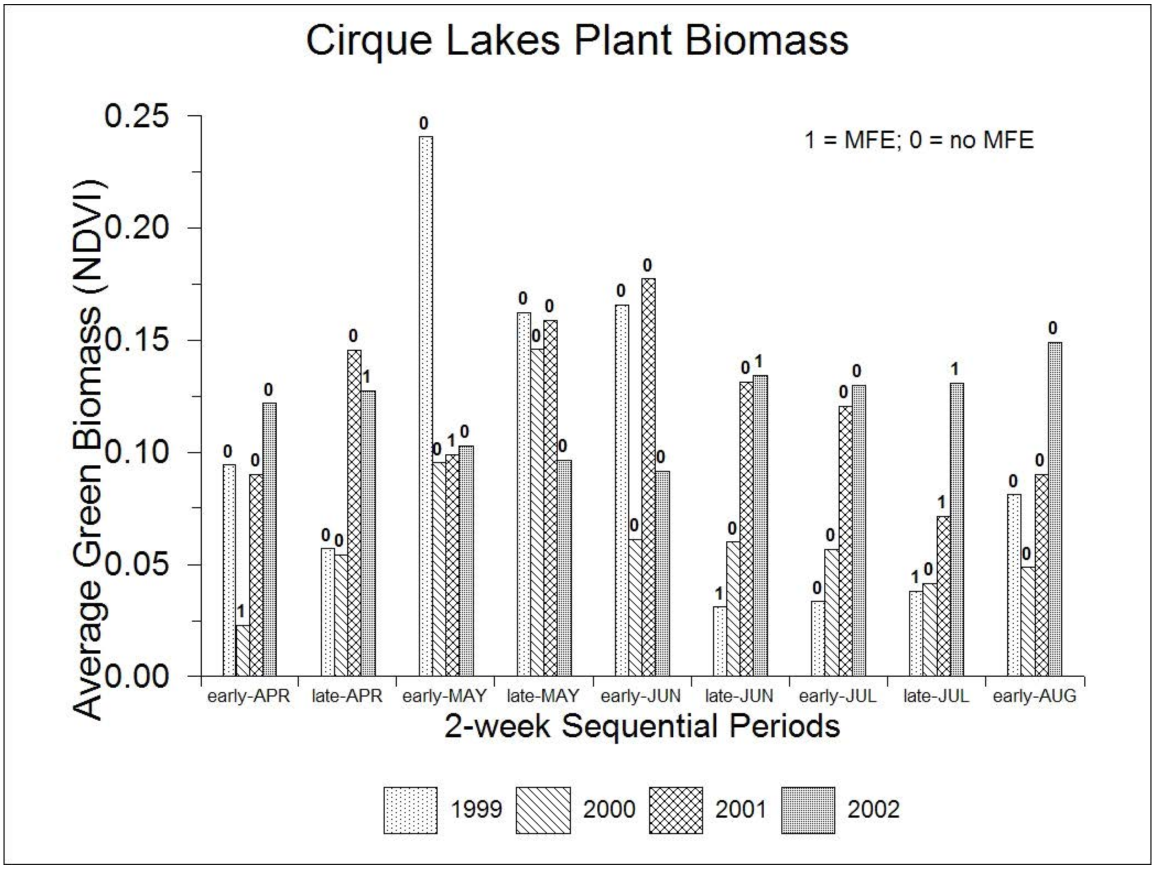


Figure 4.16. Average maximum relative green plant biomass (NDVI) at sites used by Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE). NDVI estimates obtained from a single TM image from 11 July 1994 near the peak of vegetation development for that year.

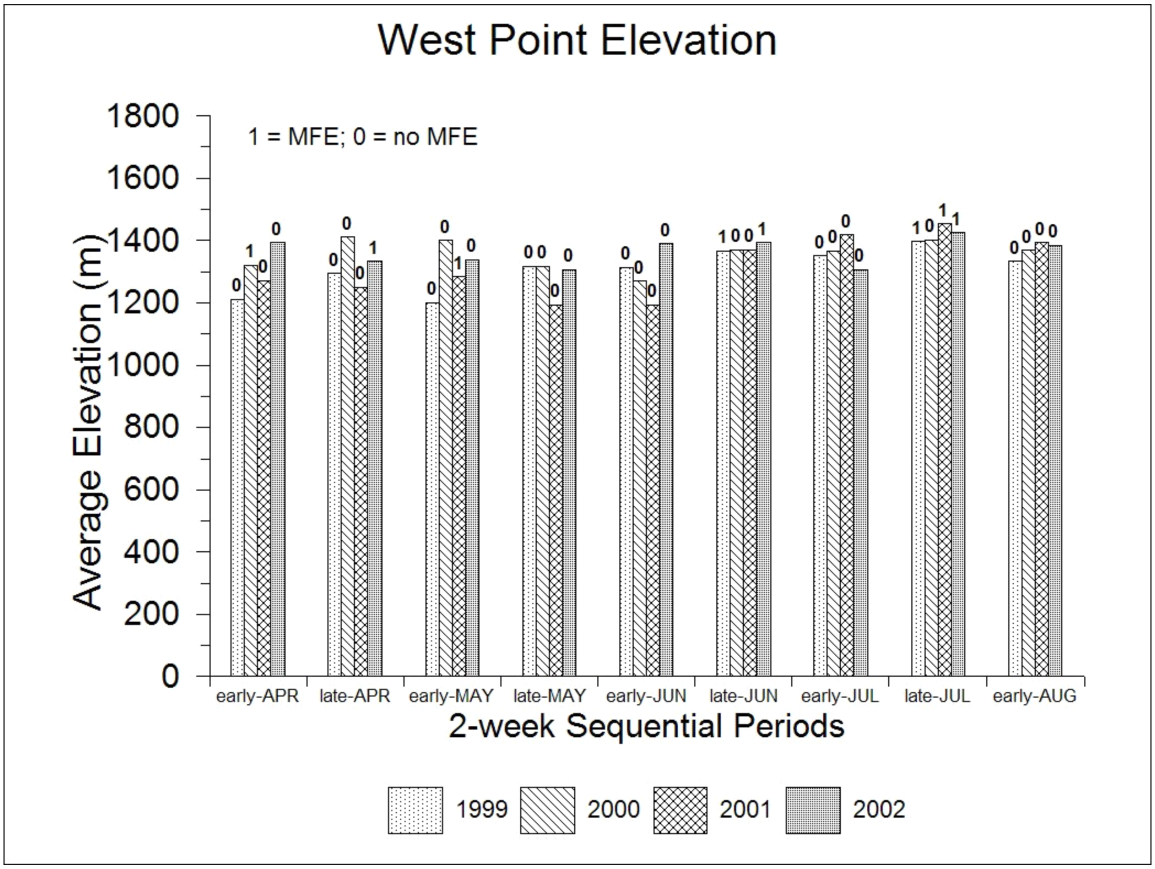


Figure 4.17. Average elevation use for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

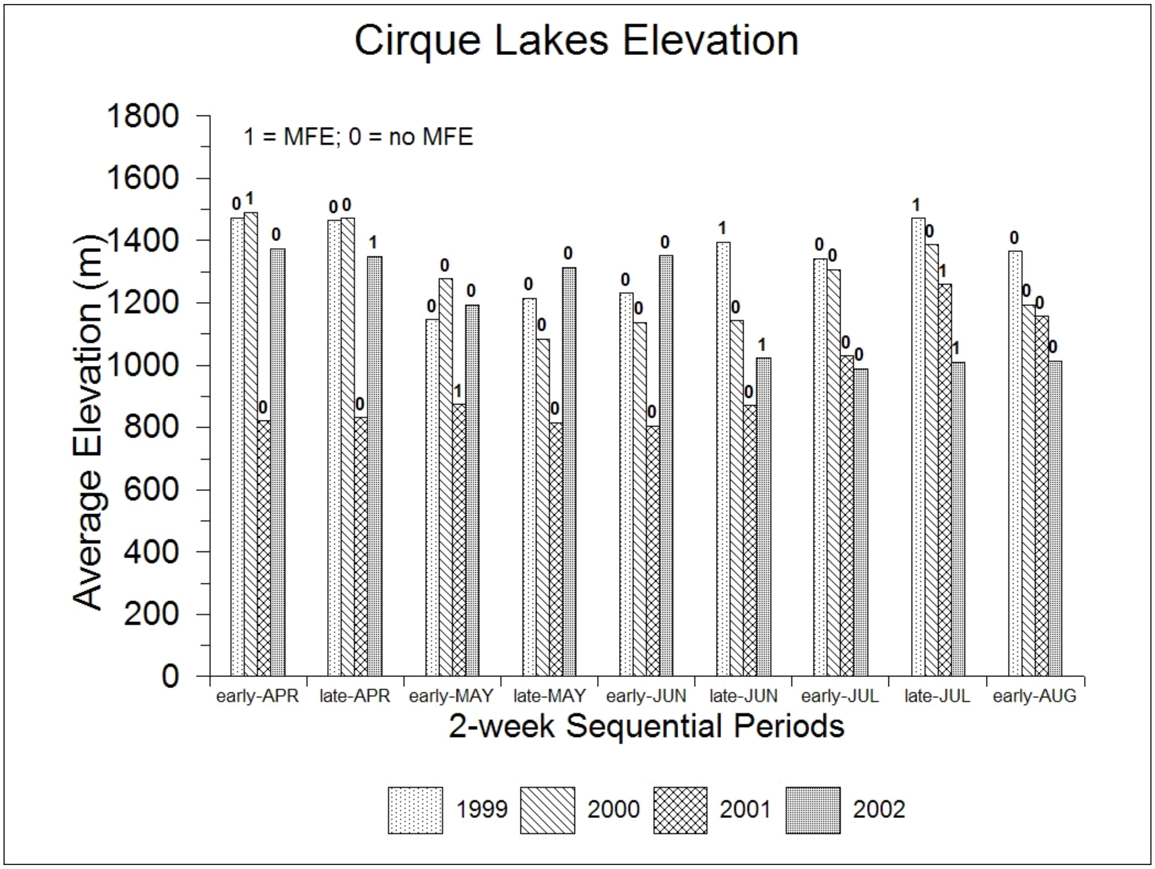


Figure 4.18. Average elevation use for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

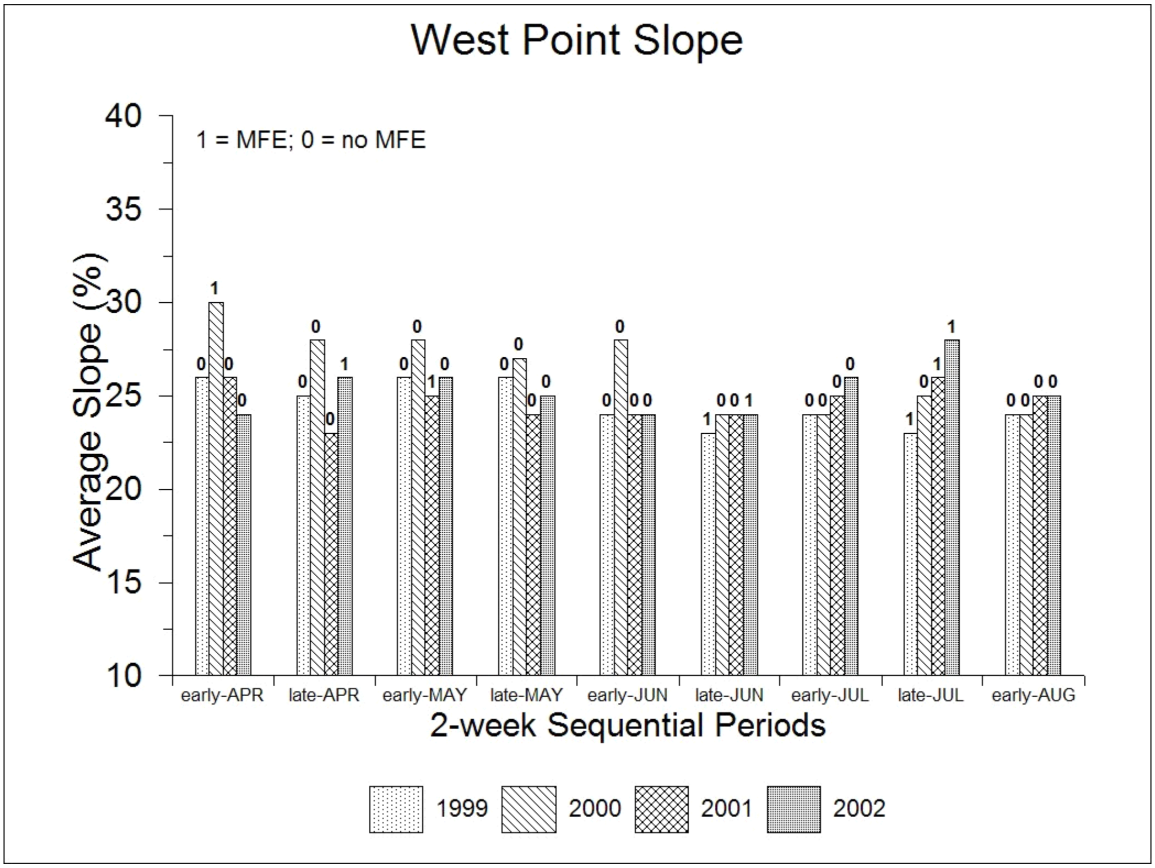


Figure 4.19. Average slope (%) use for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

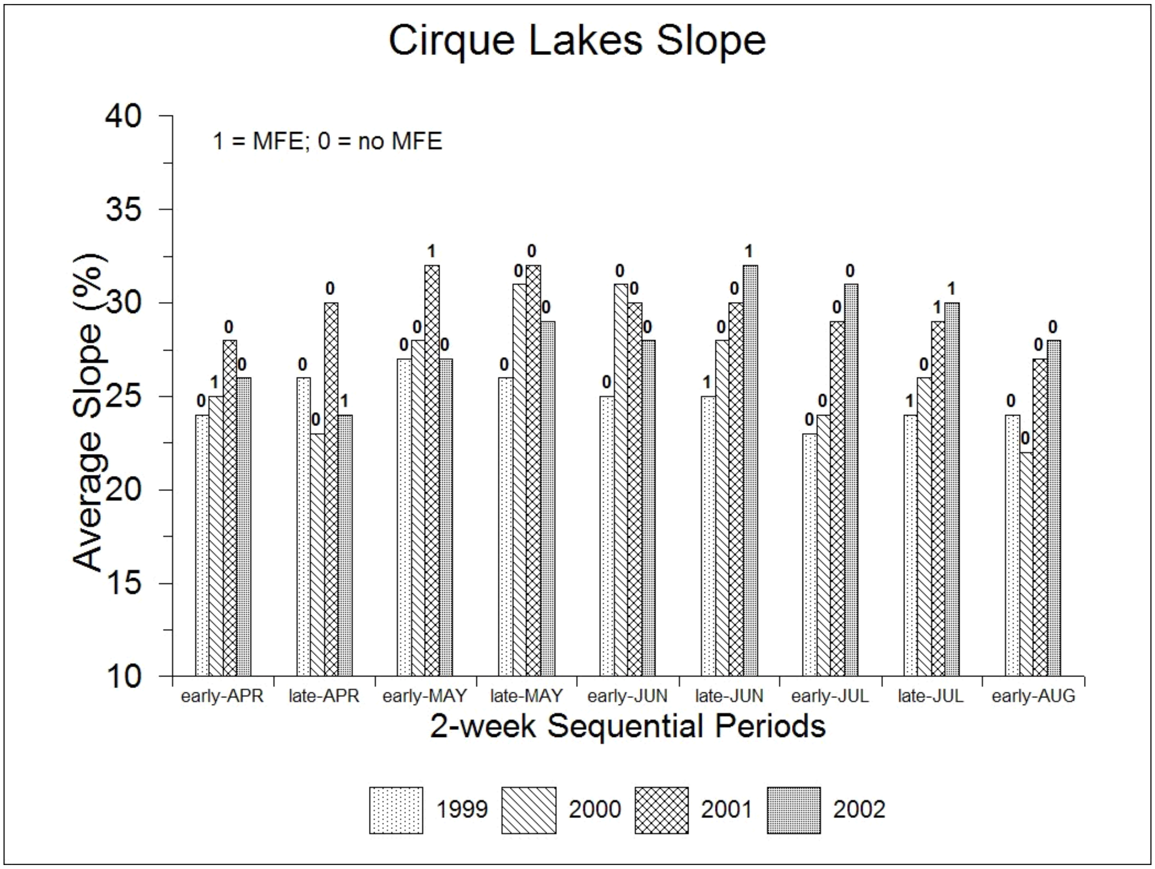


Figure 4.20. Average slope (%) use for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

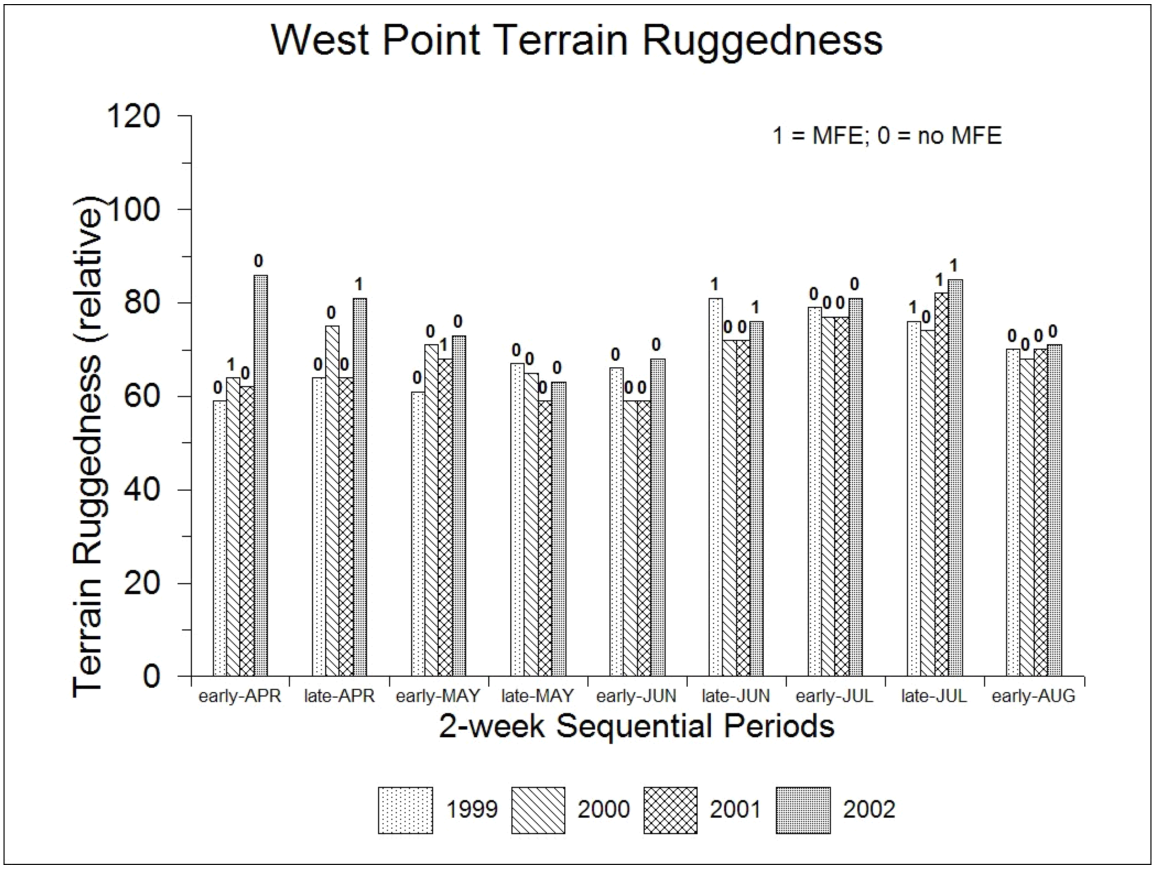


Figure 4.21. Average terrain ruggedness use for Dall’s sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

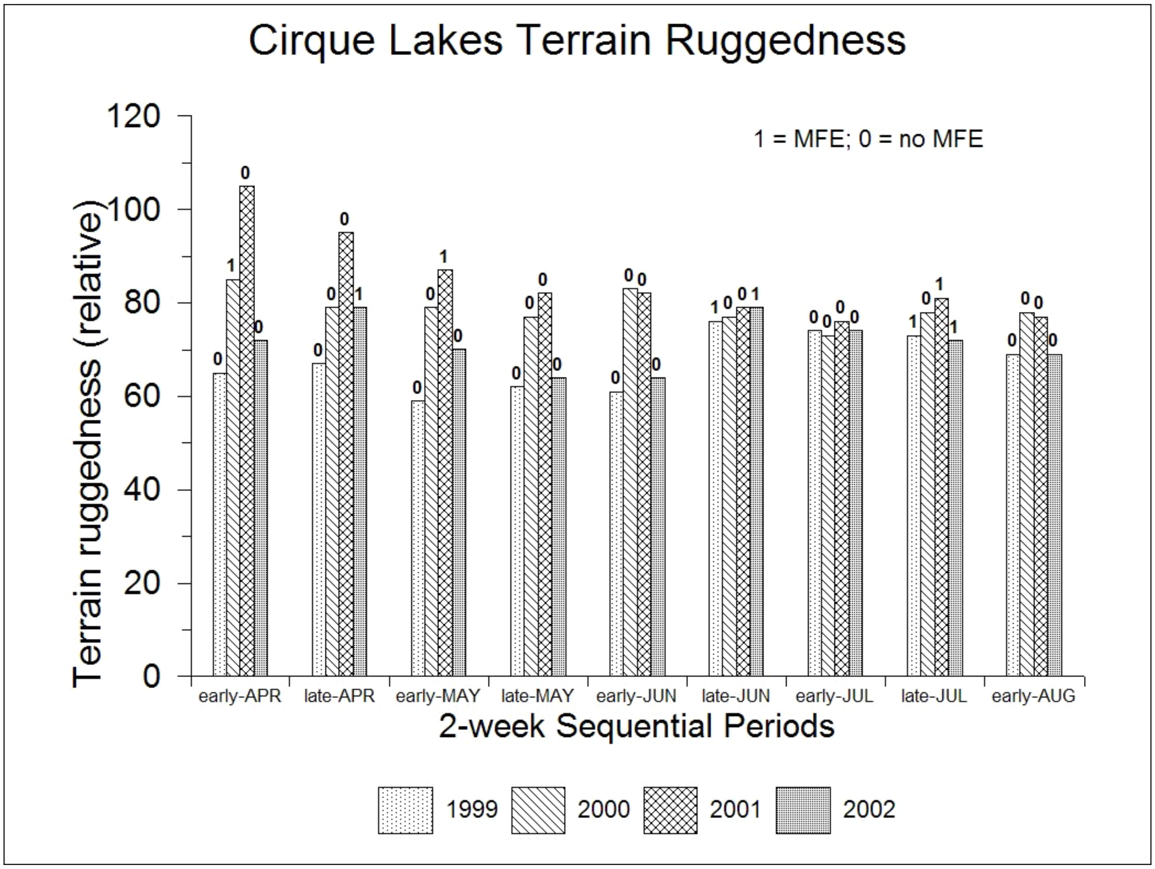


Figure 4.22. Average terrain ruggedness use for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

Proportional use of aspect differed ($P < 0.0001$) between study areas for all aspects. Sheep at both West Point (Figs. 4.23-4.26) and Cirque Lakes (Figs. 4.27-4.30) spent the greatest proportion of their time on south (0.37 and 0.43, respectively) and west (0.36 and 0.30, respectively) aspects. When sheep decreased their use of south and west aspects from late-June through early August at West Point (Figs. 4.23, 4.24) and Cirque Lakes (Figs. 4.27, 4.28) they concurrently increased their use of north and east aspects in both study areas (West Point , Figs. 4.25, 4.26; Cirque Lakes Figs. 4.29, 4.30). These shifts in proportional use of aspect were less pronounced at Cirque Lakes (Figs. 4.27-4.30) than at West Point (Figs. 4.23-4.26).

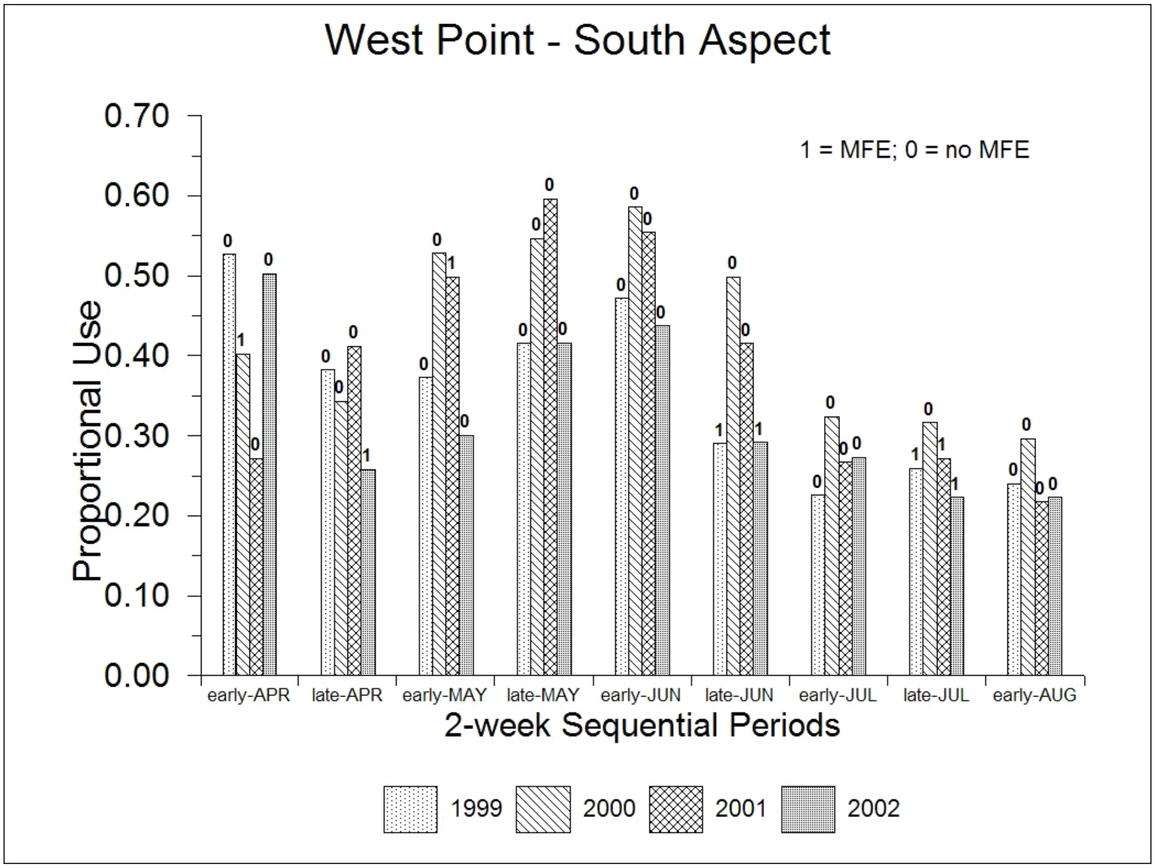


Figure 4.23. Average proportional use of southern aspects (136-225°) for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

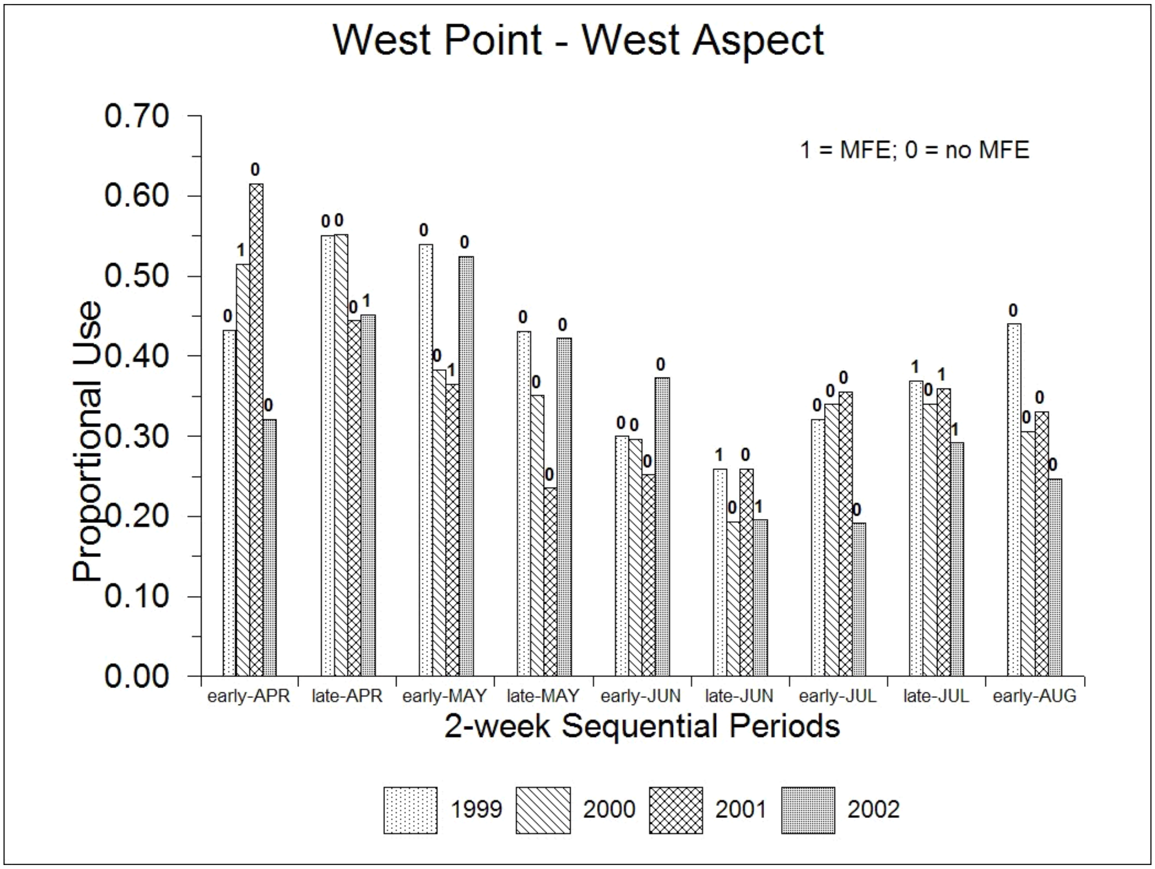


Figure 4.24. Average proportional use of western aspects (226-315°) for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

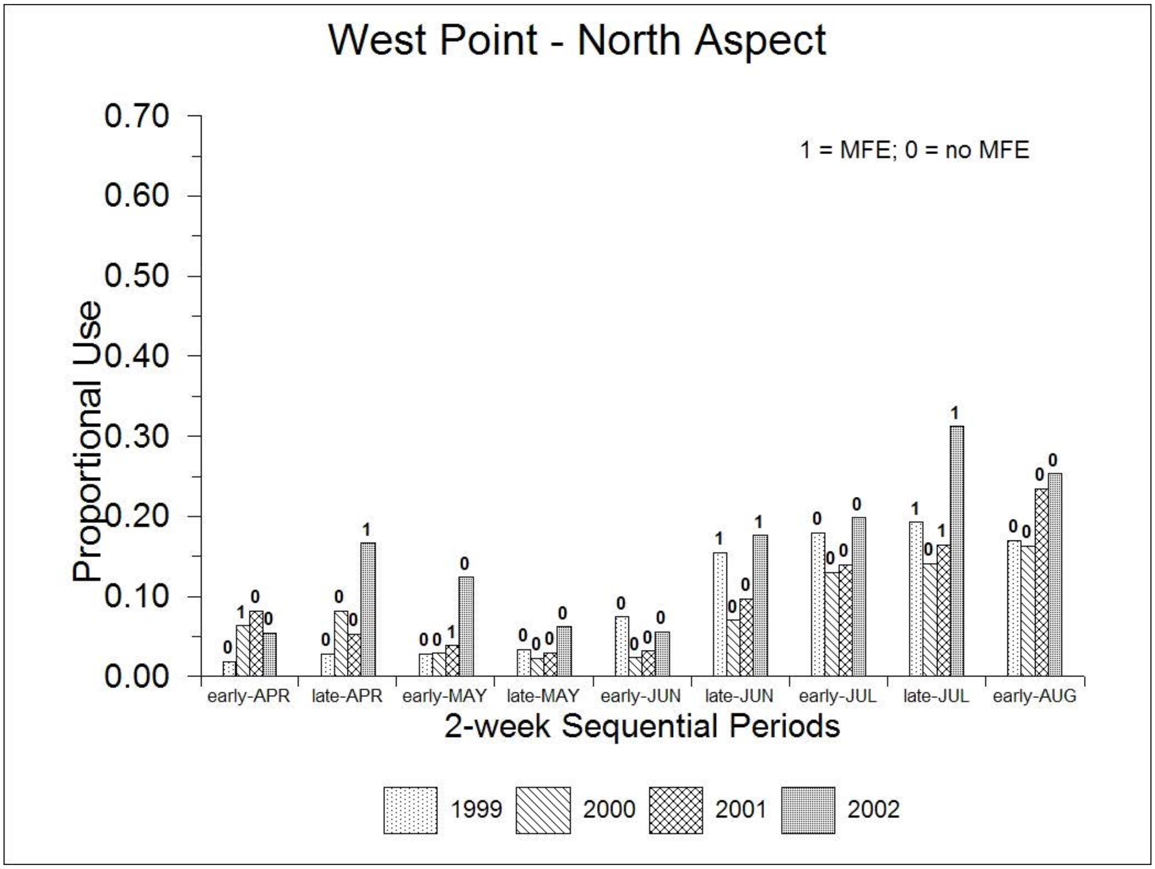


Figure 4.25. Average proportional use of northern aspects (316-045°) for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

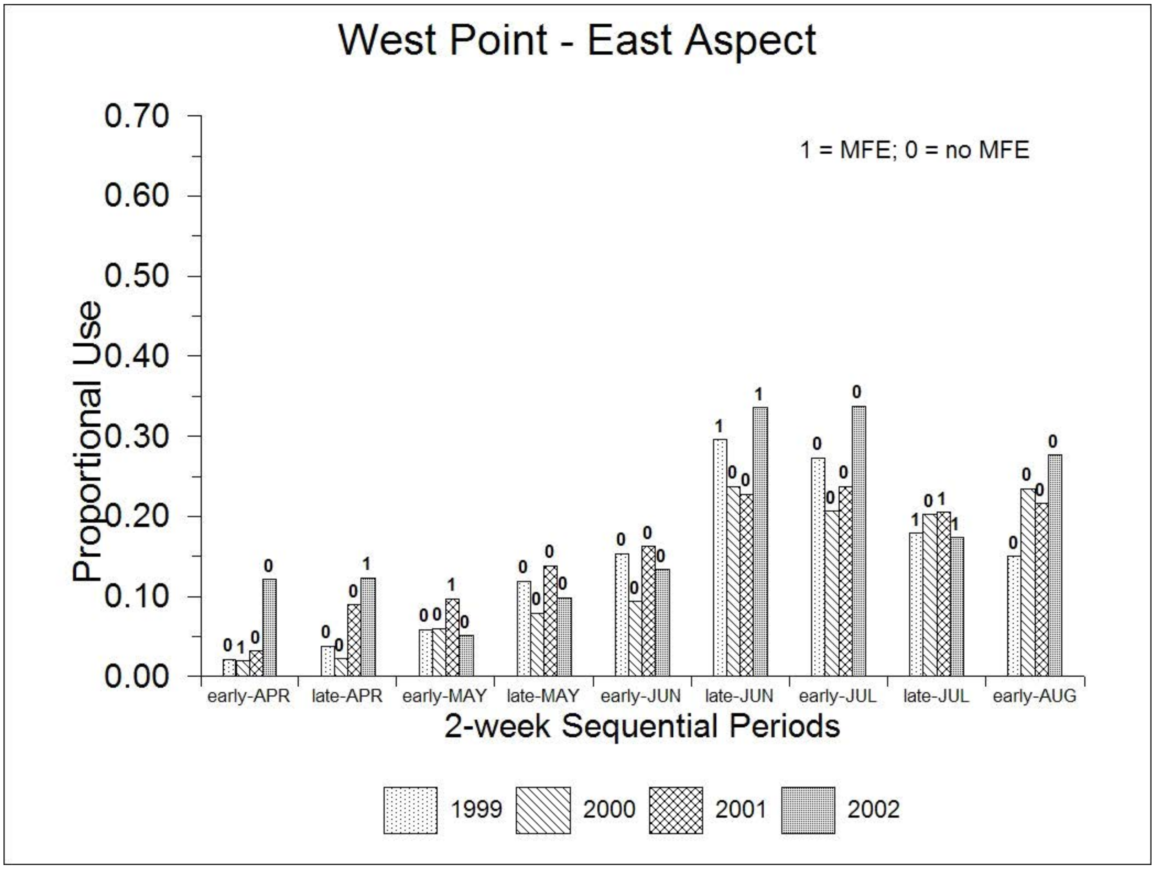


Figure 4.26. Average proportional use of eastern aspects (046-135^{o}) for Dall's sheep in the West Point study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

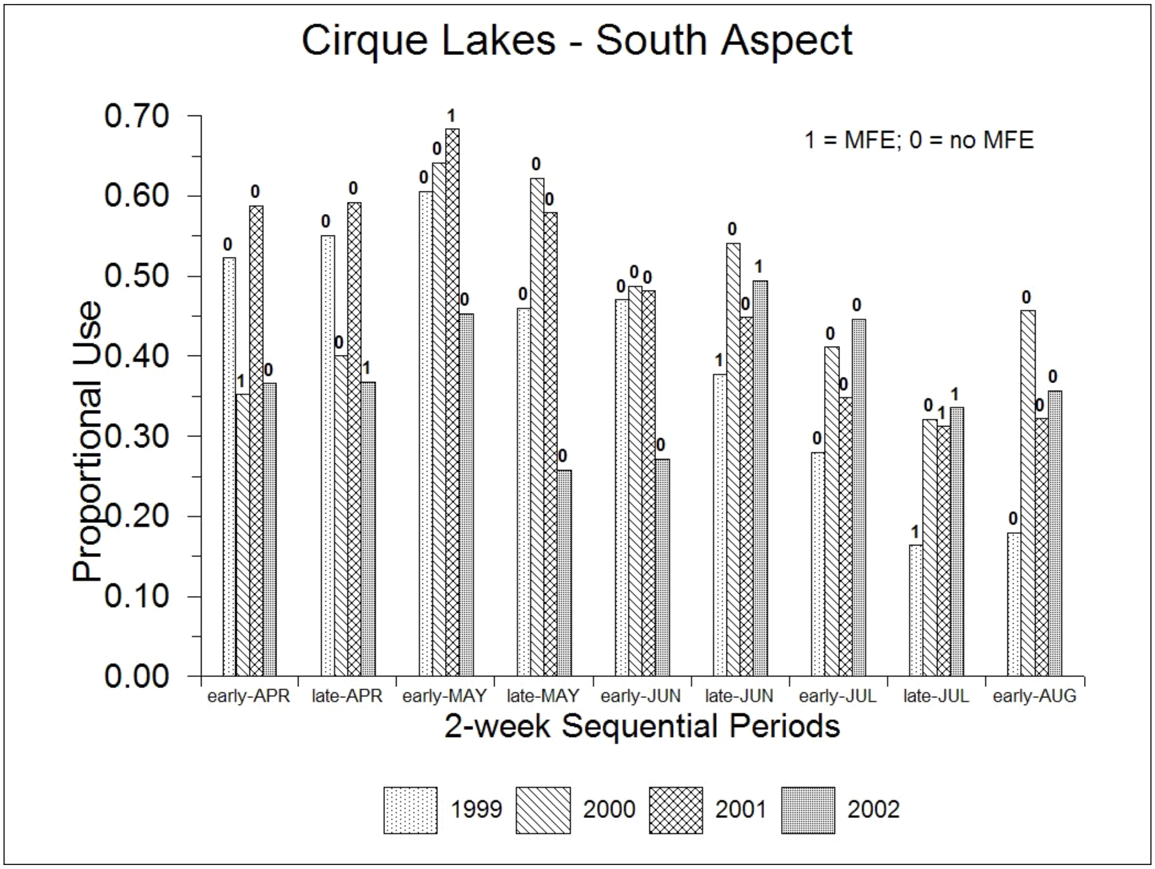


Figure 4.27. Average proportional use of southern aspects (136-225°) for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

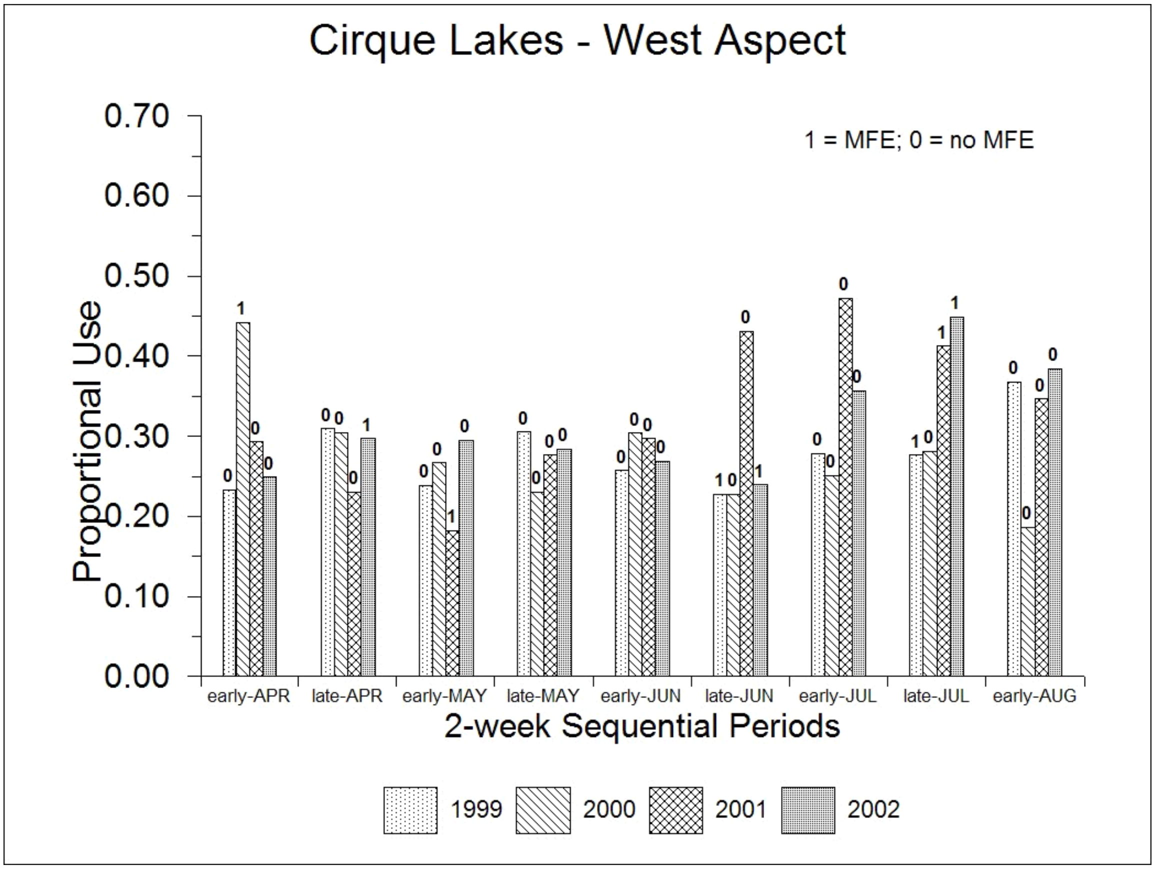


Figure 4.28. Average proportional use of western aspects (226-315^{o}) for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

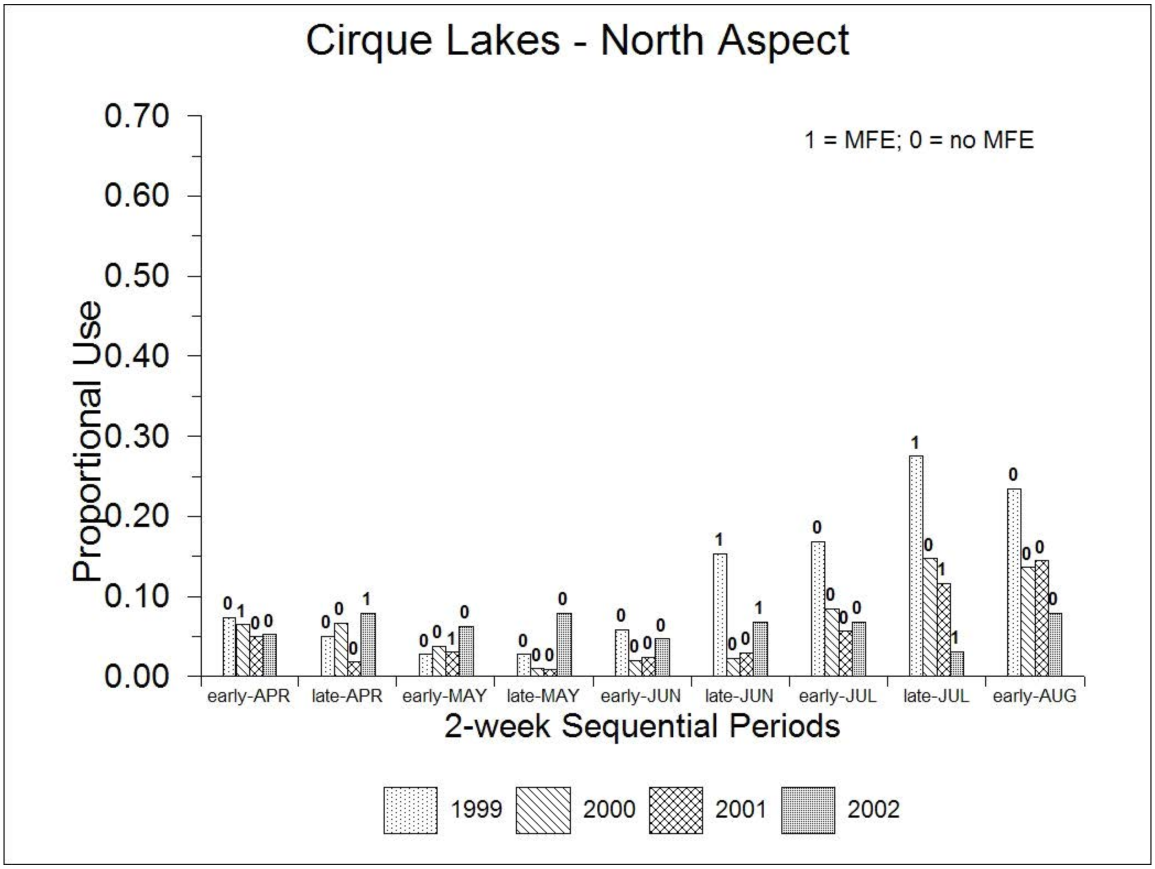


Figure 4.29. Average proportional use of northern aspects (316-045°) for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

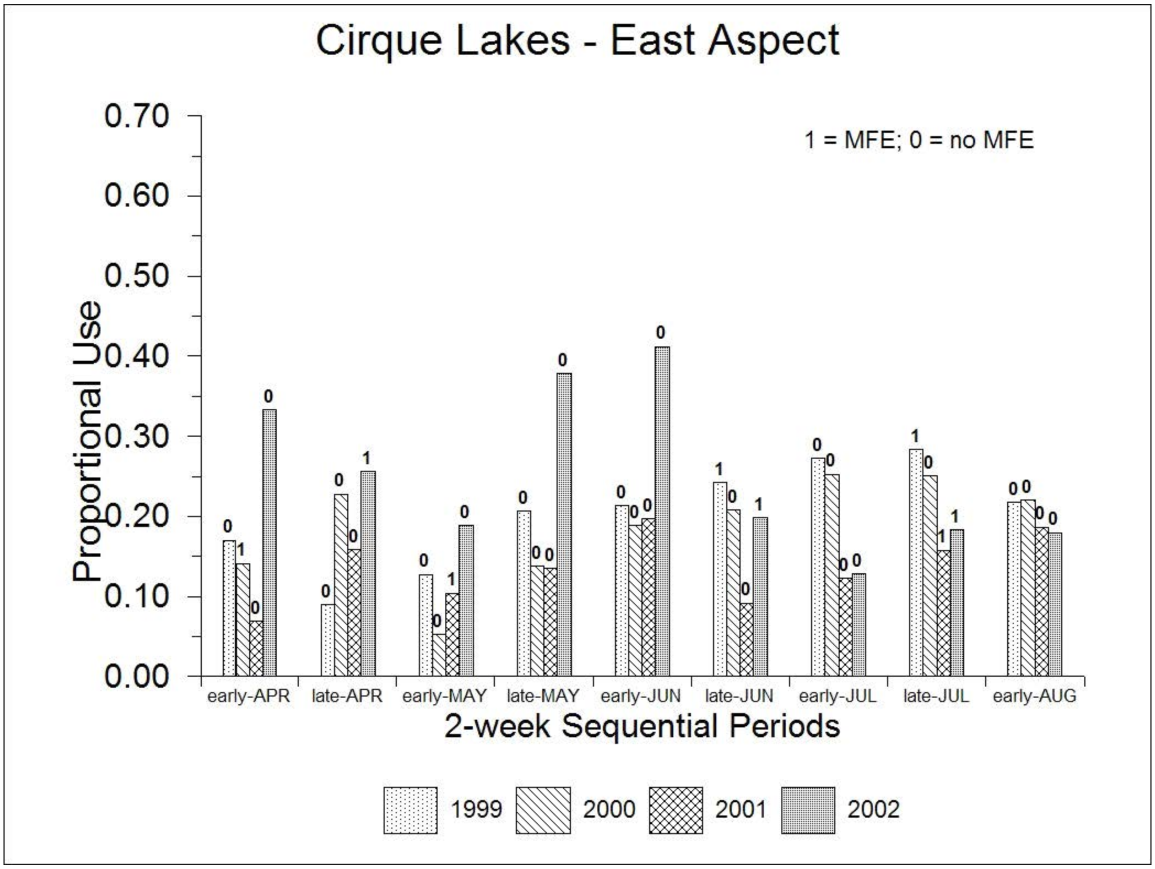


Figure 4.30. Average proportional use of eastern aspects (46-135^{o}) for Dall's sheep in the Cirque Lakes study area, interior Alaska, late-April through early-August, 1999-2002. Labels indicate presence (1) or absence (0) of major military flying events (MFE).

DISCUSSION

This portion of the study addressed sheep response at the within-home-range scale and the sampling units were the GPS collared sheep which were assumed to represent a random sample of the adult female sheep in the study area.

We observed no significant effect of the number of military aircraft sorties on 2-week within-home-range scale behavior (total distance moved, home range size) or habitat use (proportional use of landcover classes and aspect classes, average elevation, slope, terrain ruggedness, and vegetation biomass) that exceeded natural variation due to study area, year, and season. There was substantial variance in behavior and habitat use between study areas, between years within study areas, and among 2-week sequential periods within years within study areas. Once this variance was accounted for, the number of military aircraft sorties added no further explanatory power to the assessment of variance in sheep behavior and habitat use. Considering the small proportion of variance in the activity and foraging efficiency of sheep (<1%) that was explained by the number of military aircraft observed during field observation sessions (*Chapter 3, this document*), it is not surprising that we detected no effect of the number of military flight sorties on sheep behavior or habitat use at the larger, within-home-range, scale of analysis.

Because sheep in the two study areas had been exposed to military overflights for at least 21 years prior to the initiation of this study, sheep remaining in the study areas may have become acclimated to military overflights. If such acclimation had occurred, then the likelihood of detecting a significant response of sheep to military aircraft sortie levels would be diminished. Because no pre-treatment (i.e., observations without a history of military overflights) data are available, it is impossible to assess whether sheep populations and sheep performance (productivity, behavior or habitat use) have acclimated to the history of military overflights in the two study areas. However, we do note that sheep have persisted during the 22 years between establishment of the MOA's and the beginning of these studies, and remained relatively stable in numbers during the past 5 years, in both study areas which have a relatively long history of use as MOAs. Relatively low sorties/day during lambing and post-lambing (late-May and early-June; Fig. 4.1) may have minimized any potential effects of overflights on sheep.

We emphasize that the studies conducted here reflect an average background level of slightly less than 20 sorties/day which increased 3-fold to an average of about 60 sorties/day during MFEs, and that peaked at about 95 sorties/day during one year-period combination (Fig. 4.1). If average background sortie levels, average MFE sortie levels, peak sortie levels and frequency, or the seasonal pattern of sorties (Fig. 4.1) changes substantially from the values observed in this study, then the conclusions reached here regarding a detectable effect may not be applicable.

The nature of the implementation of the Cope Thunder Military Flying Exercises (MFE) prevented a direct analysis of the effects of the MFEs or the mitigation associated with the Cirque Lakes study area on within-home-range scale response of sheep. Not all scheduled MFEs were conducted, mitigation was not continuous at Cirque Lakes during implemented MFEs, and substantial numbers of sorties were launched in MOA1 and MOA2 when MFEs were not occurring. It was impossible to contrast implemented/not implemented MFEs among years while controlling for season (e.g., there was only one June in each year, an MFE was conducted or not, and implementation or not of MFEs was not balanced among years and seasons). The design of the study described here was essentially correlational because there was no control of the number of sorties launched and there were no sequential periods without sorties.

The power of the analyses were limited to some degree (Appendix F) due to relatively small number of sheep that were collared in each of the study areas that turned out to be quite different in characteristics and in behavior and habitat use by sheep. However, we did detect statistically significant differences in use of elevation and sparsely vegetated areas between the two study areas that were only ~11% of the larger value in the comparison.

Approximately 20 sheep per study area (twice as many as available) would have been required to declare the observed mean differences in behavior by sortie class (Figs. 4.2-

4.3) to be statistically significant. These mean values (Figs 4.2-4.3) suggest that home range size and distance moved within 2-week periods were quite low for the lowest sortie levels (10/sorties/day) compared to sortie levels of 20/day and greater.

Even if there had been sufficient statistical power to declare these differences (Figs. 4.2, 4.3) significant, it is not clear that the tendency toward increased home range size and distance moved for sortie levels > 10/day could have been clearly attributed to military overflights. The lowest sortie levels occurred primarily during the last trimester of pregnancy, lambing, and immediately after lambing when home range size and movement rates might naturally be expected to be low as a result of restrictions on movement of the adults by neonates.

Clear resolution of the potential effects of military aircraft sortie level on behavior and habitat use of sheep at the home range scale will require 1) replicated study areas, years, and seasons that differ only in the number of military sorties, 2) an adequate sample size of sheep ($\geq$20 collared sheep/study area), and 3) experimental control of the number of sorties that sheep are exposed to, including replicates with no sorties and replicates with no history of sorties. It is extremely unlikely that the first requirement can ever be satisfied due to the natural variance in areas, years, and seasons. The results of this study do suggest that, under the constraints of relatively few marked sheep and a system with a relatively long history of exposure to military overflights, any effects of major flying exercises on sheep behavior and habitat use were not more dramatic than the natural variance in behavior and habitat use that would be expected to result from variance among study areas, years, and seasons within years.

SUMMARY

We assessed the effect of the number of military sorties launched on home range size, movement rates, and use of habitats for Dall's sheep in interior Alaska over four years, 8 sequential 2-week-long periods within years, and two study areas. The average number of sorties launched per day was greater (59.8 sorties/day) during major flying exercises than during routine operational days (18.7 sorties/day). There was significant variation in sorties/day among years and among sequential periods within years. There was significant variation in home range size, movement rates, and habitat use between study area, among years within study areas, and among periods within years within study areas. The effect of sorties/day was never a significant source of variation in home range size, distance traveled, or habitat use, once the effects of study area, year, and period were in statistical models. The lack of demonstrated significant response by sheep to sorties/day in this study may have been due to: 1) relatively rare exposure of sheep to low, close, and loud military overflights and relatively small-magnitude behavioral response to these overflights (see Chapter 3); 2) a long period (22 years prior to study initiation) of acclimation by sheep to military overflights in the area; 3) inability to detect an effect of routine background sorties/day as we had no study area without military overflights for comparison; or 4) insufficient statistical power to detect small-magnitude effects that was a result of having a relatively small number of radio-collared sheep.

GENERAL CONCLUSIONS and MANAGEMENT IMPLICATIONS

We conclude that the levels of military activity which we observed in this study during Major Flying Exercises (~60 sorties/day) generally did not cause statistically significant effects on sheep behavior and habitat use at the home range scale when compared to the background level of military sorties (~ 20 sorties/day). When differences in feeding efficiency and activity of groups of sheep were observed, military aircraft activity accounted for a small proportion of the total variance in sheep behavior, the direction of these effects were variable, and there were no overt indications that military overflights affected sheep populations during 1999-2002. Few of the overflights that we observed were low or loud (7% of observed military overflights were below 1500 m and within 1.6 km of observed sheep) and the mitigation measures in place at the Cirque Lake study site provided no detectable reduction in sheep response to military overflights. We base these conclusions on a number of findings. Dall's sheep population in Yukon-Charley Rivers National Preserve were stable from 1997-2002. We found no differences in Dall's sheep population trends in an area mitigated for low-level military overflight verses an area that was not that could be attributable to low-level military jets. No statistical differences were found in Dall's sheep pregnancy rates, lamb to ewe ratios, yearling to ewe ratios or survival in an area mitigated for military overflights verses an area that was not. In fact, ewe body weights were higher at a non-mitigated study site verses a mitigated site. The number of overflights we observed over Dall's sheep on a given day did not influence Dall's sheep behavior. Significant differences occurred in the feeding efficiency of Dall's sheep when behavior was examined in the 10 minutes before, during and 10 minutes after an overflight event. In models that included all seasons, Dall's sheep ewe feeding efficiency was higher after the overflight event in comparison to before the overflight event. In models that just examined lambing season and early summer (May, June and July), sheep feeding efficiency was higher before the overflight event in comparison to during the event. In models that considered the proximity and sound level of overflight events, a higher proportion of sheep were active with increasing sound levels. In models that just examined lambing season and early summer, more sheep were active with closer military overflights. Factors other than military overflights explained most of the variability in the observed behavior of sheep. Of particular note in this regard was the time of year (date sequence nested within year and study site). Also of note is the rarity of low (20 overflights <1500 m) and loud (4 overflight events with 2-min mean levels $\geq$ 71dBA) military overflight events during 2 years of field work and the lack of correlation between Cope Thunders (a large scale military flying exercise) and the number of military aircraft seen by observers on the ground. Because low and loud aircraft were rare we were not able to test the effectiveness of the 5,000 foot AGL military aircraft mitigation measure at the Cirque Lake study area. Dall's sheep home ranges sizes, distances moved, and habitat use did not vary due to the number of military sorties launched per day.

Although we found little evidence of effects of military overflights on sheep, our data do suggest a number of management considerations:

1) *Sheep moved between study areas* - Considerable variation existed in number of observed sheep at individual survey units from year to year yet overall sheep

numbers in Yukon-Tanana Uplands were relatively stable. This may have been due to movement of sheep from one survey unit to another as we observed for our radiocollared sheep. Management of sheep in this area therefore, should be directed at the entire Yukon-Tanana Uplands and not at individual patches of sheep habitat. In addition, protection of sheep in the Yukon-Tanana Uplands needs to consider travel routes to suitable patches of habitat as well as the habitat patches themselves. Movement of sheep between disjunct patches of habitat could help ameliorate the affects of unfavorable conditions experienced at one habitat patch. Because travel routes are important for interchange among subpopulations (Geist 1971, Nichols and Bunnel 1999) disruption of travel routes could fragment this sheep population. Small isolated populations of sheep would be much more vulnerable to a variety of factors than would a larger contiguous sheep population.

2) *Small trend areas are not directly appropriate for assessing sheep performance in larger regions* - Variation in number of observed sheep in individual survey units from year to year yet stability in the overall sheep numbers in Yukon-Tanana Uplands suggests that small "trend areas" are not appropriate for determining trends in sheep populations in the Yukon-Tanana Uplands. To be most useful, surveys need to cover large areas including numerous patches of sheep habitat.

3) *Small sub-populations are quite variable and likely sensitive to stochastic events* - We observed substantial annual and study site variation in Dall's sheep pregnancy rates, lamb:100 ewes, and yearlings:100 ewes. Short-term or localized conditions therefore may have substantial effects on the local reproductive success of Dall's sheep and indicate that Dall's sheep subpopulations may be sensitive indicators of small scale local environmental conditions. This sensitivity needs to be considered when long-term changes in the environment are contemplated in the Yukon-Tanana Uplands. Changes in the nature of military flying activity in interior Alaska MOAs would therefore, need to be evaluated to determine how sheep populations may respond.

4) *Military overflights were less than expected and quite variable*. We observed considerable fluctuations in the extent of military flying activity from one year to the next, from one date sequence to the next, and from one Cope Thunder Exercise to the next. During the 4 years of this study, scheduled flying activities were curtailed for a number of reasons. We do not know how typical the level of flying activity we observed is for the interior Alaska MOAs. We do know that we did not evaluate the effects of military aircraft overflights levels presented as typical in the Final Environmental Impact Statement, Alaska Military Operations Areas (Department of the Air Force 1995).

5) Loud and low military jet overflights were rare events during this study. Loud and low jets can affect Dall's sheep behavior. Reduction of the potential for low and loud jets would therefore reduce the potential of affecting Dall's sheep behavior. Altitude floors, such as the 5,000 m floor associated with the current mitigation measure, is therefore an appropriate means by which to reduce potential impacts to Dall's sheep. Anecdotal observations indicate that multiple jets produced greater sound levels than did single aircraft. Therefore, a second possibility might be to restrict the number of aircraft flying together.

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APPENDIX A. Table A.1 Summary statistics for June/July aerial Dall's sheep surveys in interior Alaska Military Operations Areas.

				Total Counts				Per 100 Ewes			Rams		
Survey Unit	Year	Total Sheep	Survey Time	Ewes	Lambs	Yearlings	Rams	Lambs	Yearlings	Rams	Legal Rams	Sublegal*	% Legal
Diamond Fork	1983	7		0	0	0	7				2	5	29
	1990	19	1.70	2	2	0	15	100.00	0.00	750.00	6	9	40
	1997	11	1.80	1	0	2	8	0.00	200.00	800.00	4	4	50
	1998	37	2.00	11	5	5	16	45.45	45.45	145.45	6	10	38
	1999	18	2.70	0	0	0	18				7	11	39
	2000	NA											
	2001	41	2.40	7	4	3	27	57.14	42.86	385.71	9	18	33
	2002	55	2.50	22	5	6	22	22.73	27.27	100.00	7	15	32
Charley River	1997	39	1.40	25	11	3	0	44.00	12.00	0.00	0	0	0
	1998	53	1.00	27	19	6	1	70.37	22.22	3.70	0	1	0
	1999	52	2.08	25	16	10	1	64.00	40.00	4.00	0	1	0
	2000	31	1.63	20	6	5	0	30.00	25.00	0.00	0	0	0
	2001	31	2.55	17	9	5	0	52.94	29.41	0.00	0	0	0
	2002	81	1.65	40	30	3	8	75.00	7.50	20.00	0	8	0
Cirque Lakes	1983	66		26	10	9	21	38.46	34.62	80.77	10	11	48
	1984	27	4.80	16	4	8	1	25.00	50.00	6.25	0	1	0
	1990	107	2.50	47	15	19	26	31.91	40.43	55.32	13	13	50
	1993	58	2.50	38	9	1	10	23.68	2.63	26.32	0	10	0
	1994	63	2.60	21	9	9	24	42.86	42.86	114.29	3	21	13
	1995	76	3.20	27	9	11	29	33.33	40.74	107.41	7	22	24
	1997	77	3.20	42	13	3	19	30.95	7.14	45.24	5	14	26
	1998	62	2.10	18	9	3	32	50.00	16.67	177.78	7	25	22
	1999	69	3.65	33	13	15	8	39.39	45.45	24.24	3	5	38
	2000[+]	NA											
	2001	52	3.38	16	4	5	23	25.00	31.25	143.75	5	18	22
	2002	57	2.60	28	16	7	6	57.14	25.00	21.43	1	5	17

				Total Counts				Per 100 Ewes			Rams		
Survey Unit	Year	Total Sheep	Survey Time	Ewes	Lambs	Yearlings	Rams	Lambs	Yearlings	Rams	Legal Rams	Sublegal*	% Legal
Copper Mnt.	1983	13		1	2	1	9	200.00	100.00	900.00	0	9	0
	1990	27	1.20	9	2	9	7	22.22	100.00	77.78	3	4	43
	1997	25	0.80	9	5	3	8	55.56	33.33	88.89	4	4	50
	1998	11	0.70	5	2	1	3	40.00	20.00	60.00	1	2	33
	1999	10	1.43	4	0	0	6	0.00	0.00	150.00	2	4	33
	2000	NA											
	2001	14	1.42	6	2	2	4	33.33	33.33	66.67	2	2	50
	2002	20	0.81	9	5	1	5	55.56	11.11	55.56	1	4	20
Glacier	1993	84		42	10		32	23.81		76.19	3	29	9
Mountain#	1998	97		54	20		23	37.04		42.59	6	17	26
	1999	76		40	15		21	37.50		52.50	4	16	19
	2000	100		61	6		33	9.84		54.10	6	27	18
Mount 5580	1997	24	0.50	10	6	5	3	60.00	50.00	30.00	0	3	0
	1998	35	0.40	17	11	3	4	64.71	17.65	23.53	0	4	0
	1999	20	0.52	10	5	5	0	50.00	50.00	0.00	0	0	0
	2000	27	0.47	12	4	7	4	33.33	58.33	33.33	1	3	25
	2001	32	0.52	13	6	5	8	46.15	38.46	61.54	2	6	25
	2002	29	0.50	17	4	4	4	23.53	23.53	23.53	3	1	75
Mount Harper#	1982	87		39	8		40	20.51	0.00	102.56	18	22	45
	1993	60		30	4		26	13.33	0.00	86.67	11	15	42
	1997	83		40	9	5	29	22.50	12.50	72.50	13	16	45
	2000	69		25	9	9	26	36.00	36.00	104.00	7	19	27

				Total Counts				Per 100 Ewes			Rams		
Survey Unit	Year	Total Sheep	Survey Time	Ewes	Lambs	Yearlings	Rams	Lambs	Yearlings	Rams	Legal Rams	Sublegal*	% Legal
Mount	1983	31		9	2	0	20	22.22	0.00	222.22	5	15	25
Sorenson	1984	32	2.70	15	8	2	6	53.33	13.33	40.00	1	5	17
	1987	35		14	9	2	10	64.29	14.29	71.43	1	9	10
	1990	58	1.90	18	12	7	21	66.67	38.89	116.67	2	19	10
	1993	16	1.40	0	0	0	16				5	11	31
	1994	48	1.50	17	6	0	25	35.29	0.00	147.06	6	19	24
	1995	57	1.30	20	17	6	15	85.00	30.00	75.00	5	10	33
	1997	79	1.10	46	17	15	1	36.96	32.61	2.17	1	0	100
	1998	35	1.00	15	7	2	11	46.67	13.33	73.33	7	4	64
	1999	98	1.33	55	21	9	13	38.18	16.36	23.64	6	7	46
	2000	NA											
	2001	97	1.37	59	15	19	4	25.42	32.20	6.78	2	2	50
	2002	71	1.10	35	18	9	9	51.43	25.71	25.71	1	8	11
Twin Mountain	1983	35		12	10	3	11	83.33	25.00	91.67	1	10	9
	1990	48	1.50	15	13	4	16	86.67	26.67	106.67	0	16	0
	1997	54	1.20	23	11	4	16	47.83	17.39	69.57	4	12	25
	1998	49	0.80	23	10	6	10	43.48	26.09	43.48	3	7	30
	1999	62	0.53	22	10	6	24	45.45	27.27	109.09	6	18	25
	2000	62	1.03	22	8	4	28	36.36	18.18	127.27	6	22	21
	2001	27	0.68	3	3	0	21	100.00	0.00	700.00	7	14	33
	2002	17	0.63	3	2	0	12	66.67	0.00	400.00	5	7	42
Puzzle gulch/	1999	140	3.00	63	34	16	27	53.97	25.40	42.86	6	8	22
West point	2000#	179		82	16	32	49	19.51	39.02	59.76	19	30	39
	2001	131	2.97	67	22	9	33	32.84	13.43	49.25	9	24	27
	2002	118	2.85	62	21	9	26	33.87	14.52	41.94	6	20	23

[*] "Sublegal" rams includes all rams with horns smaller than full curl.

[+] A sheep survey was not completed at Cirque Lake during 2000.

[#] Surveys conducted by the Alaska Department of Fish and Game (Craig Gardner, Alaska Department of Fish and Game, personal communication).

APPENDIX B. Table B.1 Physical measurements of Dall's sheep captured for radiocollaring in interior Alaska during March of 1999, 2000, 2001 and 2002. Dall's sheep were captured at 2 general locations, Cirque Lake and West Point/Puzzle Gulch. Cirque Lake has mitigation measures intended to minimize the impacts of low-level military jet aircraft on Dall's sheep and West Point/Puzzle Gulch does not.

Sheep No.	Capt. Date	Wgt. (kg)	Loc.[1]	Body Con. Score[2]	Right Horn length[3*]	Left Horn length[3*]	Right Annuli	Left Annuli	Meta-tarsal*	Body*	Chest Girth*	Neck Circ. *	Tooth wear
	1999												
99-161	03/20	47.6	CL		25.5	25		5	30.5	150	95	44	Light to mod.
99-162	03/20	54.4	CL		18	25	5	6	29		102	41	Light
99-163	03/21	65.8	CL		27.5	30	6	6	29		100	42	Light to mod.
99-164	03/21	52.2	CL		Brok.	28		6	28		96.5	37	
99-165	03/21	47.6	CL		18	18	6	5	27		96	37.5	Light
99-166	03/21	45.4	CL		20	25	7	7	28.5		98	37	Light
99-167	03/22	56.7	WP		18	18	4	4	28.5		103	39	Light to mod.
99-168	03/22	63.5	WP		32	33	9	7	29.5		104	44.5	Mod. To heavy
99-169	03/21	43.1	CL		27	28	7	7	27		92	38	Mod.
99-170	03/22	63.5	WP		24	26	6	7	28.5		102	42.5	Mod. To heavy
99-171	03/19	61.2	WP		31	31	8		29	151	108	46	Mod.
99-172	03/23	65.8	WP		24.5	21.5	5	5	28		102	40	Light
99-173	03/22	65.8	WP		36	35	8	8	28.3		108	46	Mod. To heavy
99-174	03/19	61.2	WP		27.5	26.5	6	6	27.5	157	104	45.5	Mod.
99-175	03/21	59.0	CL		21	Brok.	6		28.5		100	38	Light
99-176	03/21	49.9	CL		20	21	5	5	28		98	40	Light
99-177	03/21	49.9	WP		27	27	5	5	28		104	38.5	Light to mod.
99-178	03/22	65.8	WP		28	30.5	8	8	28.3			47	Mod. To heavy
99-179	03/21	62.1	WP		26.5	26	6	6	28.2		109	48	Mod.
99-180	03/20	54.4	CL		29	21	7	7	28.5		100	40	Light
	2000												
00-161	03/16	59.0	WP	R2.5/B3/P2	31	33	7	7	28	151	110	39	Light
00-162	03/16	61.2	WP	R2.5/B2/P2	24	25	7	8	28	145	104	40	Heavy
00-163	03/16	47.6	WP	R3.5/B3.5/P2.5	22	20.5	5	5	29	147	96	43	Light
00-164	03/16	61.2	WP	R2/B2/P2	26	24	8	8	29	152	108	39	Light
00-165	03/16	65.8	WP	R3/B3/P2.5	30	28.5	8	8	30	154	127	42	Light
00-166	03/16	63.5	WP	R3.5/B3.5/P2.5	29	31	9	8	30	168	109	39	Heavy

Sheep No.	Capt. Date	Wgt. (kg)	Loc.[1]	Body Con. Score[2]	Right Horn length[3*]	Left Horn length[3*]	Right Annuli	Left Annuli	Meta-tarsal*	Body*	Chest Girth*	Neck Circ.*	Tooth wear
00-167	03/16		WP	R3/B2.5/P2	24	26	5	6	29	153	103	41	Light
00-168	03/16	52.2	WP	R3/B3/P2.5	25	29.5	6	5	29	151	113	43	Light
00-169	03/16	49.9	WP	R2.5/B2.5/P2	19.5	22	4	4	30	148	106	41	Light
00-170	03/16	61.2	WP	R3/B3/P2.5	24.5	23	4	4	29	145	107	42.5	Mod.
00-171	03/15	54.4	CL	R3/B3/P2.5	18.5	21	6	6	30	158	101	37	Heavy
00-172	03/15	49.9	CL	R2/B2/P2	28	31	9	9	30		109	41	Heavy
00-173	03/17	36.3	CL	R3.5/B3.5/P2.5	16	15	2	1	29	141	100	38	Light
00-174	03/15	54.4	CL	R2.5/B2/P2	30	22.5	9	7	29	152	104	40	Mod.
00-175	03/14	49.9	CL	R2/B2/P2	22	29	9	8	29		104	39	Light
00-176	03/15	56.7	CL	R3.5/B3.5/P3	34	33.5	9	9	29	149	102	43	Light
00-177	03/15	43.1	CL	R2.5/B2/P2	24	24	6	5	30	149	101	43	Mod.
00-178	03/14	49.9	CL	R2.5/B3/P2	25	22.5	4	4	28		100	40.5	Mod.
00-179	03/15	52.2	CL	R2.5/B2/P2	10.5	28	Brok.	7/broo	30	154	105	39	Heavy
00-180	03/14	52.2	CL		23	22	5	5	30		102	36	Light
	2001												
01-161	03/03	54.4	WP	R3/B3/P3	21.5	23.5	6	7	28.5	147	101	40	Light to mod.
01-162	03/03		WP	R3.5/B3/P3	23.5	25	6	6	28	148	99	38	Mod.
01-163	03/03	54.4	WP	R3/B3/P2.5	22	28	7	7	28	157	103	41	Light
01-164	03/02	49.9	CL	R2.5/B2/P2	25	22.5	7	6	27	144	103.5	35	Mod.
01-165	03/03	61.2	WP	R2.5/B2.5/P2	30	27	7	6	29	152	110	36	Mod.
01-166	03/02	56.7	CL	R3/B2.5/P2.5	31	29	7	7	28	140	105	40	Light to mod.
01-167	03/02	47.6	CL	R2.5/B3/P2	25	24	5	6	31	150	109	42	Light
01-168	03/03	59.0	WP	R3.5/B3.5/P3	29	30.5	7	6	29	147	105	42	Mod.
01-169	03/03	45.8	WP	R2.5/B3/P2.5	21	19.5			28	153	98	38	Light to mod.
01-170	03/03	54.4	WP	R2.5/B2.5/P2.5	32.5	32	9	9	28	145	111	37	Mod.
01-171	03/06		SB	R2.5/B2.5/P2.5	10.5	16	Brok.	3	26.5	151	96	38	Light
01-172	03/03	59.0	WP	R3.5/B3/P2.5	27	26	7	6	29	159	112	39	Mod.
01-173	03/02	52.2	WP	R2.5/B2/P2	28	28	6	6	27.5	153	106	42	Heavy
01-175	03/04		CL	R3.5/B3.5/P3	26.5	25	7	6	27	135	108	42	Mod.
01-176	03/06	57.2	SB	R3/B2.5/P2.5	27	23	7	7		153	107	42	Light
01-177	03/04		CL	R3.5/B3.5/P3	25.5	25	5	6	26.5	150	105	44	Mod.
01-178	03/02	52.2	WP	R3/B2.5/P2.5	23	22	5	5	28	149	103	36.5	Mod.
01-179	03/04	59.0	CL	R3/B3.5/P3	31	Brok.	6	Brok.	28	142	110	44	Mod. to heavy
01-180	03/04	61.2	CL	R3.5/B3.5/P3	21	25	6	6	29	154	112	43	Heavy

Sheep No.	Capt. Date	Wgt. (kg)	Loc.[1]	Body Con. Score[2]	Right Horn length[3*]	Left Horn length[3*]	Right Annuli	Left Annuli	Meta-tarsal[*]	Body[*]	Chest Girth[*]	Neck Circ.[*]	Tooth wear
	2002												
02_161	03/14	61.2	CL	R2/B2.5/P2	25.5	25	9	9	27	158	107	37	Light
02_162	03/14	61.2	CL	R3/B3/P3	26	27	4	4	29	153	111	42	Mod.
02_163	03/14	54.4	WP	R3.5/B3/P3	21	23	3	3	27.5	149	108	40	Light
02_164	03/13	65.8	CL	R3/B2.5/P2.5	24	25	7	8	28.5	161	112	44	Mod.
02_165	03/13	56.7	WP	R2.5/B2.5/P2	26	25	8	7	27.5	165	107	44.5	Light
02_166	03/14	47.6	CL	R2/B2.5/P2	21	23	7	7	26.5	147	102.5	39	Mod.
02_167	03/14	59.0	WP	R3/B3/P3	20	22	6	6	28	160	105	43	Light
02_168	03/14	65.8	CL	R3/B3/P2.5	23	24	7	7	30	147	113	39	Mod.
02_169	03/13	56.7	WP	R3/B2.5/P2.5	27.5	26	5	6	28.5	155	112	43	Mod.
02_170	03/14	59.0	CL	R3/B3/P3	27.2	28	9	8	29	157	109	35	Mod.
02_171	03/13	59.0	WP	R3/B3/P2.5	27	24	9	9	27.5	153	113	44	Mod.
02_172	03/13	56.7	WP	R2.5/B2.5/P2	22	23	7	7	28	159	110.5	45	Mod.
02_173	03/12	49.9	CL	R2/B2.5/P2.5	24	24	8	8	27		103.5	36.5	Light
02_174	03/12	54.4	CL	R3/B3/P3	25	23	6	5	28	129	103	35	Mod.
02_175	03/14	56.7	CL	R2.5/B2/P2	32	Brok.	6	Brok.	27	155	107	41.4	Mod.
02_176	03/13	65.8	WP	R3/B3/P3	29.5	28.5	10	10	30	157	114	36	Mod.
02_177	03/13	54.4	WP	R3/B3.5/P3	25	26	7	8	28	150	110	38.5	Light
02_178	03/14	65.8	CL	R3/B3/P2.5	29.5	30	10	10	28.5	162	112	47	Heavy
02_179	03/13	47.6	WP	R3/B3/P3	21	21	6	6	26.5	152	102	42.5	Light
02_180	03/12		CL	R2.5/B2/P2.5	26	25.5	8	6	27.5	156	106	43	Light

[1] CL = Cirque Lake, WP = West Point/Puzzle Gulch, SB = Sheep bluff, a known sheep area in close proximity to Cirque Lake.
[2] Body condition scores were determined by palpating animals at: 1) Ribs (R); 2) Back/withers (B); and 3) hip-pin (P) or rump. Scores were a subjective rating from 1 to 5 (1 = emaciated, 5 = obese).
[3] Brok. = Horn broken, Broo = horn broomed on tip.
[*] Length, girth and circumference were measured in cm.

APPENDIX C. Table C.1. Incidental mammal and bird species observed (or tracks observed) while watching Dall's sheep (*Ovis dalli*) in February, March, April and May of 2000, and during March, May June and July of 2001.

MOA SHEEP PROJECT 2000

Animals/Tracks Observed	Cirque Lakes	West Point
Mammals		
Caribou (*Rangifer tarandus*)		Feb, May
Dall's sheep (*Ovis dalli*)	Feb, April, May, July	Feb, April, May, July
Fox (*Vulpes vulpes*)	Feb	Feb, May
Grizzly Bear (*Ursus arctos*)	May	May
Hoary Marmot (*Marmota caligata*)	May, July	May
Marten (*Martes americana*)	Feb	
Moose (*Alces alces*)		May
Otter (*Lontra Canadensis*)	Feb	
Pika (*Ochotona collaris*)	Feb, April, May, July	Feb, May
Red Squirrel (*Tamiasciurus hudsonicus*)	Feb, April	
Ermine (*Mustela erminea*)	May	
Snowshoe Hare (*Lepus americanus*)		Feb, May
Wolf (*Canis lupus*)	Feb	Feb, April
Wolverine (*Gulo gulo*)	Feb, April	Feb, April, May
Birds		
American Robin	May	May
American tree-sparrow	May, July	May
Boreal Chickadee	Feb	May
Common Raven	April, May, July	
Common Red polls	May, July	May
Common Snipe	May	May
Evening Grosbeak		May
Fox Sparrow	May	May
Golden Eagle		May
Gray -headed junco		May
Gray Jay	April	May
Gray-cheeked thrush		May
Gray-crowned rosey finch	May, July	May
Gyrfalcon	Feb., April, May	Feb, May
Hermit Thrush	May	
Horned Lark	July	
Lapland Longspur	May, July	
Long-tailed duck	July	
Northern harrier	May	May
Northern Shrike		May
Northern Wheatear	July	May
Osprey	July	

Animals/Tracks Observed	Cirque Lakes	West Point
Birds		
Rock Ptarmigan	Feb., April	Feb, May
Ruby-Crowned kinglet		May
Savannah Sparrow	May	
Say's phoebe		May
Scaup sps.	July	
Scoter sps.	July	
Townsend Solitaire	May	May
Upland Sandpiper	May	
Varied thrush		May
Water pipit	May, July	May
White winged crossbill	April	
White-crowned Sparrow	May, July	May
White-winged scoter	July	
Willow Ptarmigan	Feb., April	
Yellow-rumped warbler		May

MOA SHEEP PROJECT 2001

Animals/Tracks Observed	Cirque Lakes	West Point
Mammals		
Black Bear (*Ursus americanus*)		May
Caribou (*Rangifer tarandus*)	May	July
Dall's sheep (*Ovis dalli*)	March, May, June, July	March, May, June, July
Fox (*Vulpes vulpes*)		March
Grizzly Bear (*Ursus arctos*)	May, June	May
Hoary Marmot (*Marmota caligata*)	May	
Lynx (*Lynx canadensis*)		May
Moose (*Alces alces*)		March
Pika (*Ochotona collaris*)	May	March
Red -backed vole (*Clethrionomys rutilus*)	May	
Ermine (*Mustela erminea*)	May	
Wolf (*Canis lupus*)	May	
Wolverine (*Gulo gulo*)	March, May, June, July	March, May, June, July
Birds		
American Robin	May	
American tree-sparrow	May	
Bohemian Wax-wing	May	
Bonaparte's Gull	July	
Boreal Chickadee		March
Boreal Owl	May	
Common Raven	May	March

Animals/Tracks Observed	Cirque Lakes	West Point
Birds		
Common Red polls	May	March
Flicker	May	
Fox Sparrow	May	
Golden Eagle	May	May
Goshawk		March
Gray -headed junco	May	
Gray Jay	May	March
Gray-crowned rosey finch	May	
Gyrfalcon	May	
Horned Lark	May	
Lapland Longspur	May	
Long-tailed duck	July	
Merlin	May	
Northern harrier	May	
Red-necked phalarope	July	
Rock Ptarmigan	May	March
Rough-legged hawk	May	
Ruby-Crowned kinglet	May	
Say's phoebe	May	
Scaup sps.	July	
Scoter sps.	July	
Townsend Solitaire	May	
Water pipit	May	
White-crowned Sparrow	May	
White-winged scoter	July	
Yellow-rumped warbler	May	

APPENDIX D. Results from microhistological (Tables D.1-D.4) and nitrogen analysis (D.5) of sheep pellets in 2 study areas in the Yukon-Tanana Uplands, Alaska. Microhistological analysis was conducted by the Wildlife Habitat Nutrition Laboratory, University of Washington, Pullman, WA. Proportion of plant composition of fecal pellets was determined at a plant species level using 4 slides per sample and by looking at 25 views per slide. Nitrogen content of fecal pellets was determined by the the Chemical Nutrition Laboratory, University of Alaska, Fairbanks, Alaska. Nitrogen content was determined by combustion in a LECO auto-analyzer. .

Table D.1. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area and month in the Yukon-Tanana Uplands, Alaska, 2000.

	Cirque Lake				**West Point**			
Plants	Feb.	April	May	July	Feb.	April	May	July
Betula stem							0.8	
Dryas leaf	1.9	0.7	2.4		1.0	2.4	4.1	1.1
Dryas stem			2.0		0.3	1.2	0.6	0.5
Ledum		0.5		0.2	0.5		0.3	
Populus leaf								1.1
Rhododendron						1.9	1.9	
Rosa leaf		0.5						
Rosa stem							0.5	
Rubus discolor		0.1						
Salix leaf/hair			0.4			0.5	1.1	3.2
Salix stem	0.8	1.4	1.2	0.4	0.8	1.4	2.5	0.3
Vaccinium leaf			1.4		0.8			0.8
Vaccinium stem			0.8					
Total Shrubs	2.7	3.2	8.2	0.6	3.4	7.4	11.8	7.0
Agropyron	1.3	1.1	3.2	0.6	0.8	2.4	1.6	1.1
Arctogrostis				1.6				
Calamagrostis purpurascens	1.6	4.1	2.2	0.8	2.8	0.7	1.1	2.7
Festuca altaica	11.0	14.5	8.0	7.3	16.8	9.2	18.6	5.9
Hierochloe alpina	1.9	3.7	1.6	0.4		1.7	1.6	0.3
Poa spp.	9.4	7.8	6.2	6.7	7.6	8.4	11.5	4.9
Other Grasses		0.5	3.2	2.4	1.5	3.6	1.9	
Total Grasses	25.2	31.7	24.4	19.8	29.5	26.0	36.3	14.9
Carex bigelowii	5.4	5.3	2.2	25.8	1.0	3.1	4.7	23.2
Carex microchaeta	0.3	1.1						
Carex spp.	8.9	7.1	2.0	14.3	1.3	3.9	2.2	12.7
Eriophorum			1.0					
Juncus/Luzula	1.6		0.4	24.2	0.5	1.0	1.1	22.9
Total Sedge/Rush	16.2	13.5	5.6	64.3	2.8	8.0	8.0	58.8
Arabis hirsuta		0.5	0.3	0.2				
Artemisia spp.				0.4				

	Cirque Lake				West Point			
Plants	Feb.	April	May	July	Feb.	April	May	July
Astragalus						1.2	0.6	
Equisetum	0.5							
Lupinus/Lotus						1.7	0.3	2.7
Silene menziesii			4.2		0.5		0.6	
Other Forbs	0.3	0.5	0.2	1.4		1.7	0.3	
Total Forbs	0.8	1.0	4.7	2.0	0.5	4.6	1.8	2.7
Alectoria/Bryoria	1.9		1.0	0.8	1.3			0.5
Cetraria/Dactylina	3.5	3.0	11.5	0.4	1.5	5.6	5.5	1.6
Cladina/Cladonia	4.9	5.5	12.5	3.0	7.9	3.9	6.0	0.5
Peltigera	9.2	6.2	4.8	2.8	5.6	7.0	3.8	9.4
Other Lichen			1.0					
Total Lichen	19.5	14.7	30.8	7.0	16.3	16.5	15.3	12.0
Aulacomnium	7.0	5.3	3.4	0.6	3.1	1.2	4.4	1.9
Classic Moss*	22.9	26.5	21.3	5.5	44.1	35.3	21.6	2.7
Polytrichum	5.7	3.9	1.6		0.3	1.0	0.8	
Sphagnum		0.2		0.2				
Total Mosses	35.6	35.9	26.3	6.3	47.5	37.5	26.8	4.6
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Classic moss includes Dicranum, Bryum, Hypnum, Pohlia and several other mosses that are difficult to differentiate in microhistological samples.

Table D.2. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area and month in the Yukon-Tanana Uplands, Alaska, 2001.

	Cirque Lake				West Point		
Plants:	March	May	June	July	March	June	July
Arctostaphylos alpina stem							
Artemisia spp.			0.5				0.1
Betula nana stem		0.9					
Dryas octopetala leaf		0.3	3.7	0.1	0.4	5.4	1.4
Dryas octopetala stem	1.1	1.0				0.7	
Empetrum nigrum leaf		0.9	1.4				
Ledum palustre leaf	0.9	0.7	0.5	0.2	0.2		
Rhododendron lapponicum leaf					0.6	0.7	
Rosa acicularis stem					0.6	0.5	
Salix spp. leaf			3.3	0.5	0.6	2.0	2.4
Salix spp. leaf/catkin			0.5				
Salix spp. stem	2.4	2.3	1.4		1.1	1.8	0.2
Vaccinium spp. leaf				1.4			
Vaccinium spp. stem	0.6		0.7				
Shrub leaf			0.2				0.6
Shrub stem				0.1	0.4	1.0	0.7
Total Shrubs	5.0	6.1	12.2	2.3	3.9	12.1	5.4
Agropyron spicatum	0.4	1.0	1.0	1.1	2.6	1.8	1.1
Calamagrostis purpurascens	1.9	3.3	6.1	2.7	5.5	10.5	7.1
Festuca altaica	10.0	8.4	17.3	10.1	26.6	16.0	27.2
Hierochloe alpina		2.6	1.6	1.1	1.5	4.3	0.2
Poa spp.	8.6	7.1	14.7	6.6	14.7	8.5	11.0
Unkown Grasses	0.2	1.6	3.7	1.6	2.6	4.5	1.6
Total Grasses	21.1	24.0	44.4	23.2	53.5	45.6	48.2
Carex bigelowii	7.7	1.9	7.0	19.9	3.4	4.0	4.8
Carex spp.	18.8	9.4	21.9	28.9	5.3	8.0	15.5
Eriophorum spp.					0.6		
Luzula/Juncus	4.9	5.6	3.3	11.5	5.3	3.8	9.1
Total Sedges/Rushes	31.4	16.9	32.2	60.3	14.6	15.8	29.4
Antennaria friesiana			3.8	0.1			
Arabis hirsuta			0.2				
Astragalus/Oxytropis				0.2	0.1	0.5	0.9
Equisetum spp.						0.5	0.4
Lupinus spp.		0.4		0.4	0.4	0.2	1.5
Polygonum spp.						1.0	
Potentilla spp.			0.5				1.5
Saxifraga spp.	0.6	1.0				0.2	
Silene menziesii		0.4					
Unknown Forbs	0.4	0.7	1.6	0.1	0.8		2.0

Total Forbs	1.0	2.5	6.1	0.8	1.3	2.4	6.3
	Cirque Lake				**West Point**		
Plants:	March	May	June	July	March	June	July
Alectoria/Bryoria/Usnea	1.7	1.6	0.9	1.4	1.3	3.0	0.9
Cetraria/Dactilina	2.1	5.4	0.9	2.5	2.1	5.3	2.0
Cladonia/Cladina	6.4	11.2	2.4	3.0	4.9	2.3	0.7
Foliose Lichen (Peltigera type)	7.3	4.0		2.2	4.7	1.2	5.1
Total Lichen	17.5	22.2	4.2	9.1	13.0	11.8	8.7
Aulacomium moss	0.2	1.0		1.3	1.5		
Classic moss	11.8	9.1		3.0	9.4	8.0	2.0
Dicranum moss	6.8	13.4	0.2		2.6	2.3	
Polytrichum moss	3.9	3.5			0.2	2.0	
Selaginella sibirica			0.7				
Sphagnum spp. moss	1.3	1.0					
Unknown Moss		0.3					
Total Mosses	24.0	28.3	0.9	4.3	13.7	12.3	2.0
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Classic moss includes Dicranum, Bryum, Hypnum, Pohlia and several other mosses that are difficult to differentiate in microhistological samples.

Table D.3. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area and month in the Yukon-Tanana Uplands, Alaska, 2002.

	Cirque Lake	**West Point**
Plants:	March	March
Arctostaphylos alpina stem		1.4
Artemisia spp.	1.3	
Betula nana stem		
Dryas octopetala leaf	0.2	0.6
Dryas octopetala stem		
Empetrum nigrum leaf		
Ledum palustre leaf		1.4
Rhododendron lapponicum leaf		0.8
Rosa acicularis stem	0.8	
Salix spp. leaf		1.1
Salix spp. leaf/catkin		
Salix spp. stem	0.8	0.3
Vaccinium spp. leaf		
Vaccinium spp. stem		
Shrub leaf		0.5
Shrub stem		
Total Shrubs	3.1	6.1
Agropyron spicatum	2.3	1.4
Calamagrostis purpurascens	4.0	3.3
Festuca altaica	14.6	19.7
Hierochloe alpina	0.5	0.6
Poa spp.	6.8	3.6
Unkown Grasses	2.3	2.5
Total Grasses	30.5	31.1
Carex bigelowii	2.8	3.0
Carex spp.	8.3	5.0
Eriophorum spp.		
Luzula/Juncus	7.3	4.4
Total Sedges/Rushes	18.4	12.4
Antennaria friesiana		
Arabis hirsuta		
Astragalus/Oxytropis	0.2	0.3
Equisetum spp.		
Lupinus spp.	1.5	
Polygonum spp.		
Potentilla spp.		0.6
Saxifraga spp.		0.3
Silene menziesii		
Unknown Forbs	0.8	0.6

Total Forbs	2.5	1.8

	Cirque Lake	West Point
Plants:	March	March
Alectoria/Bryoria/Usnea	2.5	3.6
Cetraria/Dactilina	4.0	1.7
Cladonia/Cladina	3.5	3.6
Foliose Lichen (Peltigera type)	5.0	5.8
Total Lichen	15.0	14.7
Aulacomium moss	0.8	0.6
Classic moss	17.1	30.8
Dicranum moss	6.3	1.4
Polytrichum moss	5.0	1.1
Selaginella sibirica		
Sphagnum spp. moss		
Unknown Moss	1.3	
Total Mosses	30.5	33.9
TOTAL	100.00	100.00

* Classic moss includes Dicranum, Bryum, Hypnum, Pohlia and several other mosses that are difficult to differentiate in microhistological samples.

Table D.4. Summary of percent occurrence by forage group in microhistological samples of fecal pellets from Dall's sheep, by study area, month and year in the Yukon-Tanana Uplands, Alaska.

Forage	Cirque Lakes						West Point					
Group	February	March	April	May	June	July	February	March	April	May	June	July
Shrubs	2.7		3.2	8.2		0.6	3.4		7.4	11.8		7.0
Grasses	25.2		31.7	24.4		19.8	29.5		26.0	36.3		14.9
Sedges/Rushes	16.2		13.5	5.6		64.3	2.8		8.0	8.0		58.8
Forbs	0.8		1.0	4.7		2.0	0.5		4.6	1.8		2.7
Lichens	19.5		14.7	30.8		7.0	16.3		16.5	15.3		12.0
Mosses	35.6		35.9	26.3		6.3	47.5		37.5	26.8		4.6
Shrubs		5.0		6.1	12.2	2.3		3.9			12.1	5.4
Grasses		21.1		24.0	44.4	23.2		53.5			45.6	48.2
Sedges/Rushes		31.4		16.9	32.2	60.3		14.6			15.8	29.4
Forbs		1.0		2.5	6.1	0.8		1.3			2.4	6.3
Lichens		17.5		22.2	4.2	9.1		13.0			11.8	8.7
Moss		24.0		28.3	0.9	4.3		13.7			12.3	2.0
Shrubs		3.1						6.1				
Grasses		30.5						31.1				
Sedges/Rushes		18.4						12.4				
Forbs		2.5						1.8				
Lichens		15.0						14.7				
Moss		30.5						33.9				

Table D.5. Percent nitrogen in fecal pellets of Dall's sheep by study area, year and month in the Yukon-Tanana Uplands, Alaska.

	2000		2001	
Month	Cirque Lakes	West Point	Cirque Lakes	West Point
February	1.62	1.47		
March	1.70	1.50	1.69	1.47
April	1.63	1.67		
May	1.24	1.75	1.65	
June			2.43	1.79
July	2.67	2.76	2.61	1.94

APPENDIX E. Graphical and statistical analysis of the proportion of time Dall's sheep spent active, the feeding efficiency, and behavior of Dall's sheep relative to overflights by small civilian single engine fixed wing aircraft.

Table E.1. Summary of ANCOVA results examining factors affecting the proportion of time Dall's sheep were active including the relation to overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Proportion Active (ewe/overflight model)	Rock	1	3.539	0.062	0.022
	Ewe	1	0.161	0.689 [a]	0.001
	Overflight	2	0.308	0.735	0.004
	Site	1	4.544	0.035	0.027
	Year(site)	2	3.290	0.040	0.039
	Sequence(year(site))	12	2.897	0.001	0.178
Proportion Active (lamb/overflight model)	Rock	1	0.118	0.732	0.001
	Ewe	1	0.212	0.646	0.002
	Lamb	1	1.019	0.315	0.011
	Overflight	2	0.466	0.629	0.010
	Site	1	0.020	0.888 [a]	0.000
	Year(site)	1	0.181	0.672	0.002
	Sequence(year(site))	5	0.521	0.759	0.027

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after small single engine aircraft overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.

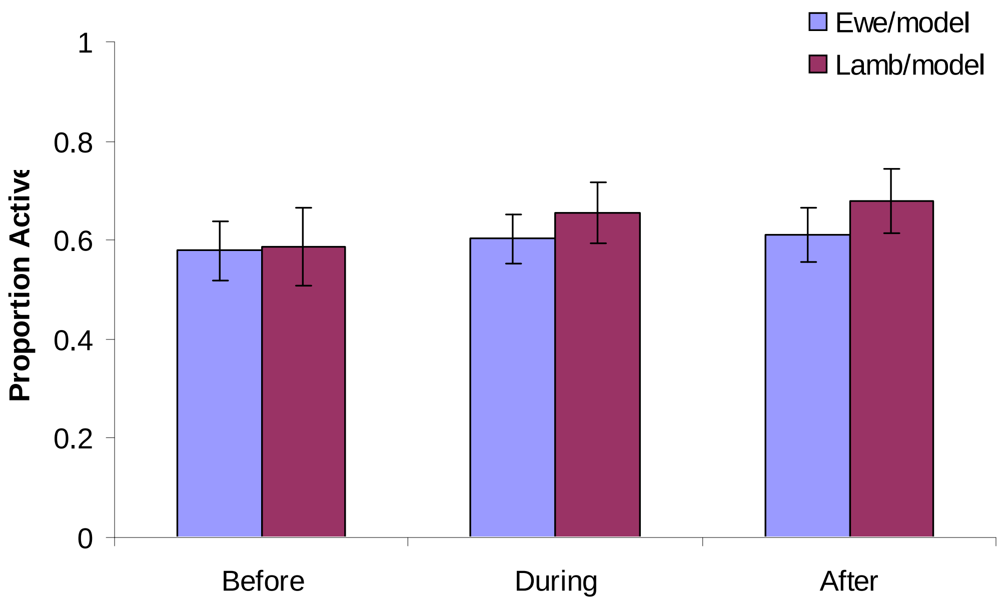


Figure E.31. Mean (±SE) proportion of Dall's sheep active during scan sampling in: 1) the 10 minutes before a small single engine aircraft overflight event (*n*=50 for ewe model and *n*=29 for lamb model); 2) during a small single engine aircraft overflight event (*n*=75 for ewe model and *n*=44 for lamb model); and 3) 10 minutes after the overflight event (*n*=56 for ewe model and *n*=33 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Table E.2. Summary of ANCOVA results examining factors affecting the feeding efficiency of Dall's sheep including the relation to overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent variable*	*d.f.*	*F*	*P*	Partial eta squared
Feeding Efficiency (ewe/overflight model)	Rock	1	0.115	0.736	0.001
	Ewe	1	0.782	0.379	0.007
	Overflight	2	5.795	0.004	0.097
	Site	1	0.115	0.735	0.001
	Year(site)	2	1.624	0.202	0.029
	Sequence(year(site))	11	1.089	0.377	0.100
Feeding Efficiency (lamb/overflight model)	Rock	1	0.062	0.804	0.001
	Ewe	1	0.381	0.539	0.006
	Lamb	1	3.801	0.055	0.053
	Overflight	2	1.939	0.152	0.054
	Site	1	0.000	.991	0.000
	Year(site)	1	0.029	0.865	0.000
	Sequence(year(site))	5	1.450	0.218	0.096

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after an overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.

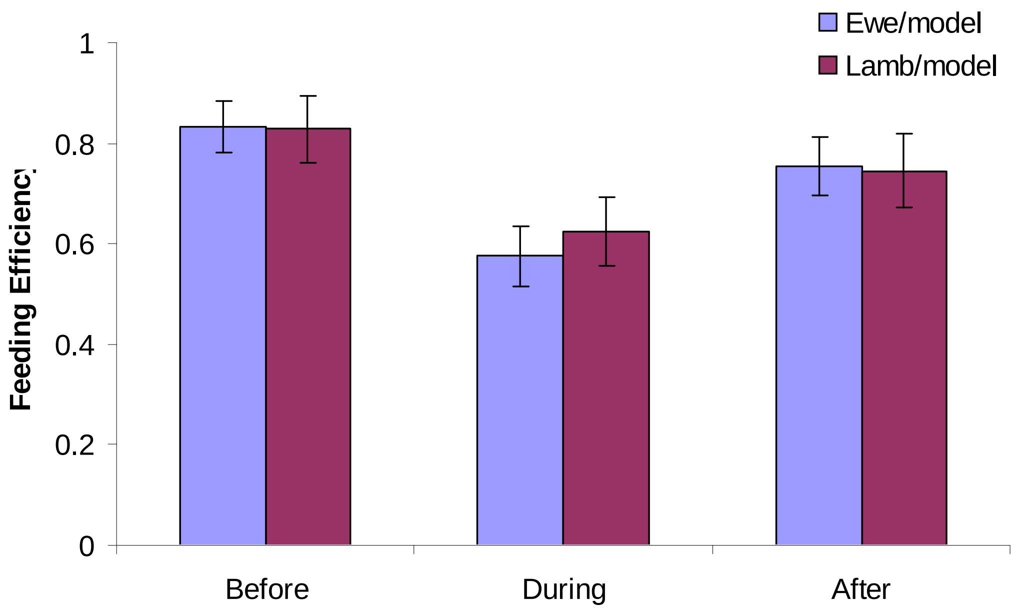


Figure E.32. Mean (+SE) feeding efficiency of Dall's sheep during scan sampling in: 1) the 10 minutes before a small single engine aircraft overflight event (*n*=37 for ewe model and *n*=22 for lamb model); 2) during a small single engine aircraft overflight event (*n*=50 for ewe model and *n*=34 for lamb model); and 3) 10 minutes after the overflight event (*n*=40 for ewe model and *n*=25 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Table E.3. Summary of MANCOVA results examining factors affecting the behavior of Dall's sheep (percent bedding, standing, feeding, walking, and running) including the relation to overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent Variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Behavior					
ewe/overflight	Rock	4	1.085	0.366	0.027
model	Ewe	4	0.223	0.925 [a]	0.006
	Overflight	8	2.187	0.028	0.052
	Site	4	1.345	0.256	0.033
	Year(site)	8	1.910	0.058 [a]	0.046
	Sequence(year(site))	48	2.247	0.000	0.145
Behavior					
(lamb/overflight	Rock	4	0.152	0.962	0.007
model)	Ewe	4	0.390	0.815	0.017
	Lamb	4	1.490	0.212	0.062
	Overflight	8	1.732	0.094	0.071
	Site	4	0.033	0.998 [a]	0.001
	Year(site)	4	0.218	0.928 [a]	0.010
	Sequence(year(site))	20	1.738	0.027	0.087

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) before, during, or after a small single engine aircraft overflight event; 5) study site; 6) year nested within study site; and 7) date sequence nested within year nested within study site

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.

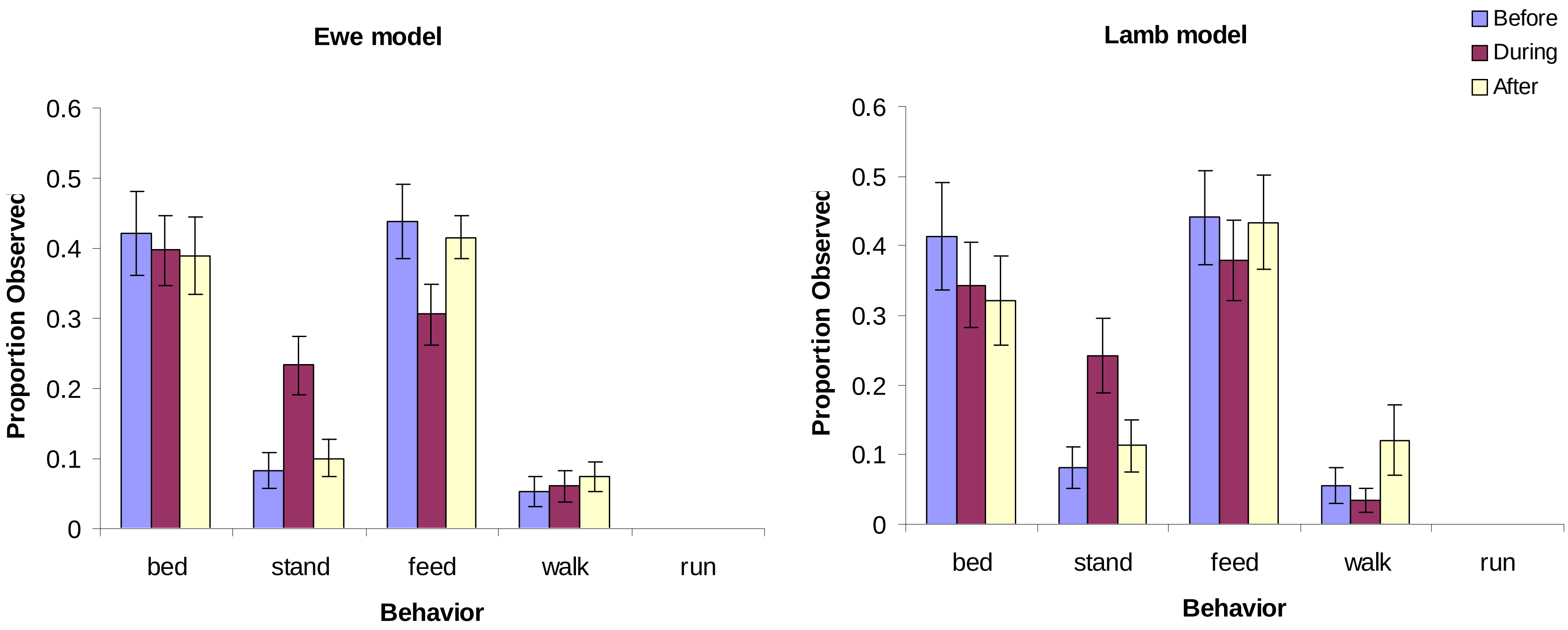


Figure E.33. Mean (±SE) behavior of Dall's sheep during scan sampling in: 1) the 10 minutes before a small single engine aircraft overflight event (*n*=50 for ewe model and *n*=29 for lamb model); 2) during a small single engine aircraft overflight event (*n*=75 for ewe model and *n*=44 for lamb model); and 3) 10 minutes after the overflight event (*n*=56 for ewe model and *n*=33 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Table E.4. Summary of ANCOVA results examining factors affecting the proportion of time Dall's sheep were active including proximity and sound level (2 min. mean L_{eq} [dBA]) of overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Proportion Active (ewe/sound model)	Rock	1	6.986	0.014	0.212
	Ewe	1	12.477	0.002 [a]	0.324
	Proximity	2	0.367	0.697 [a]	0.027
	L_{eq} (dBA)	1	3.437	0.075 [a]	0.117
	Site	1	7.077	0.013 [a]	0.214
	Year(site)	2	5.602	0.009 [a]	0.301
	Sequence(year(site))	8	1.463	0.219	0.310
Proportion Active (lamb/sound model)	Rock	1	9.006	0.008 [a]	0.360
	Ewe	1	13.342	0.002	0.455
	Lamb	1	0.720	0.409	0.043
	Proximity	2	2.693	0.048	0.050
	L_{eq} (dBA)	1	3.976	0.063	0.199
	Site	1	9.110	0.008	0.363
	Year(site)	1	9.030	0.008 [a]	0.361
	Sequence(year(site))	3	3.179	0.053 [a]	0.373

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity to sheep of overflight by small civilian single engine aircraft; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) year nested within study site nested within date sequence.

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.

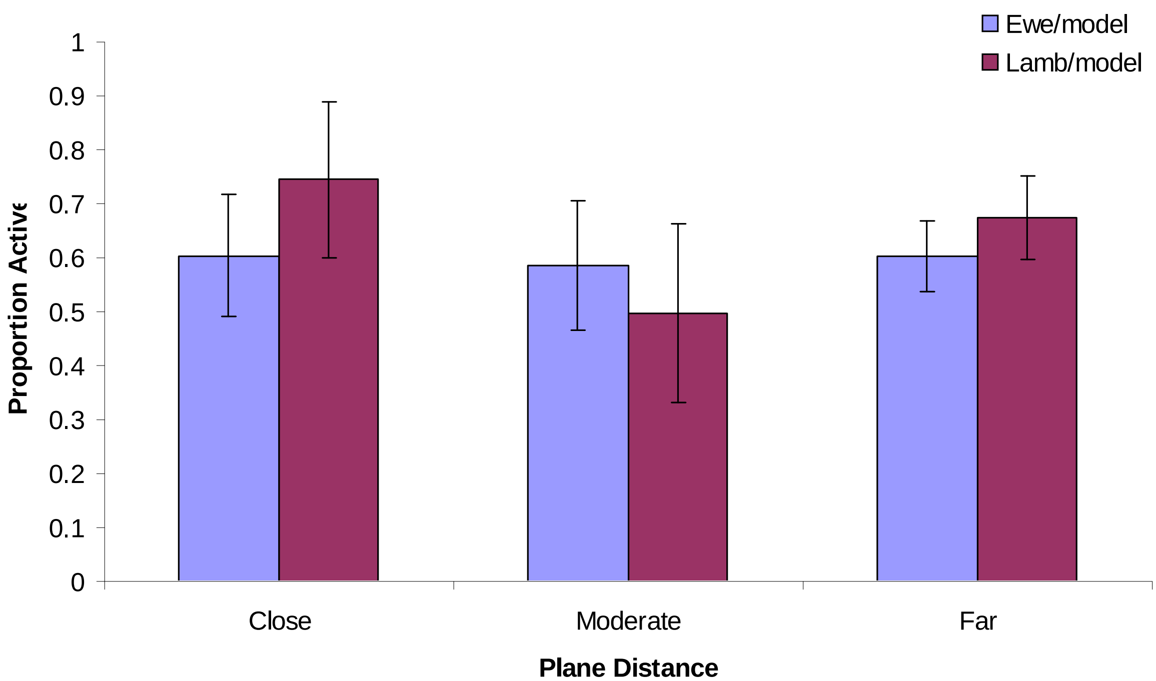


Figure E.34. Mean (+SE) proportion of Dall's sheep active during scan sampling during overflights by small civilian single engine aircraft grouped by proximity: 1) close = aircraft lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=15 for ewe model and *n*=7 for lamb model); 2) moderate = aircraft lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=15 for ewe model and *n*=8 for lamb model); 3) far = aircraft higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=44 for ewe model and *n*=28 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

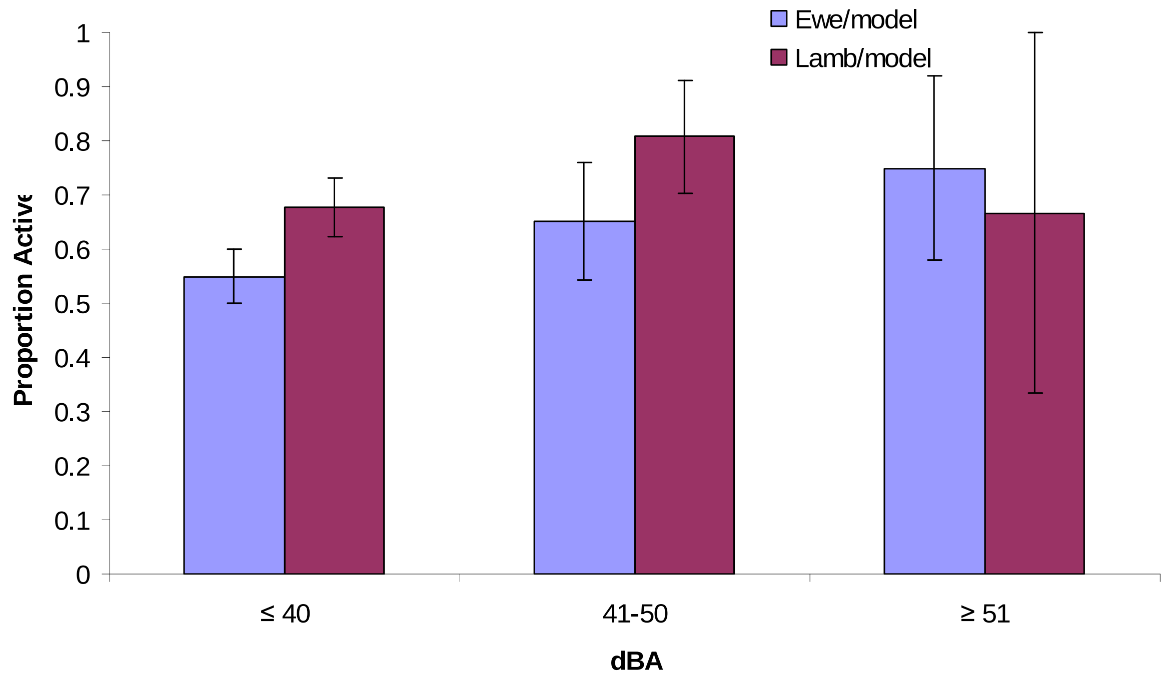


Figure E.35. Mean (±SE) proportion of Dall's sheep active during scan sampling during overflights by small civilian single engine aircraft grouped by 2 minute mean L_{eq} (dBA): 1) ≤ 40 dBA (*n*=77 for ewe model and *n*=53 for lamb model); 2) 41 – 50 dBA (*n*=16 for ewe model and *n*=10 for lamb model); and 3) ≥ 51 dBA (*n*=6 for ewe model and *n*=3 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Table E.5. Summary of ANCOVA results examining factors affecting the feeding efficiency of Dall's sheep including proximity and sound level (2 min. mean L_{eq} [dBA]) of overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent variable	Independent variable*	*d.f.*	*F*	*P*	Partial eta squared
Feeding Efficiency (ewe/sound model)	Rock	1	0.019	0.893	0.002
	Ewe	1	0.014	0.907 [a]	0.001
	Proximity	2	0.581	0.574	0.088
	L_{eq} (dBA)	1	0.947	0.350	0.073
	Site	1	0.019	0.894	0.002
	Year(site)	2	0.009	0.991	0.002
	Sequence(year(site))	6	1.248	0.349	0.384
Feeding Efficiency (lamb/sound model)	Rock	1	0.112	0.745 [a]	0.011
	Ewe	1	0.000	0.998	0.000
	Lamb	1	1.667	0.226 [a]	0.143
	Proximity	1	1.000	0.395	0.024
	L_{eq} (dBA)	1	0.030	0.866	0.003
	Site	1	0.112	0.744	0.011
	Year(site)	1	0.113	0.743 [a]	0.011
	Sequence(year(site))	2	0.693	0.522	0.122

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity of overflight to sheep; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) year nested within study site nested within date sequence.

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.

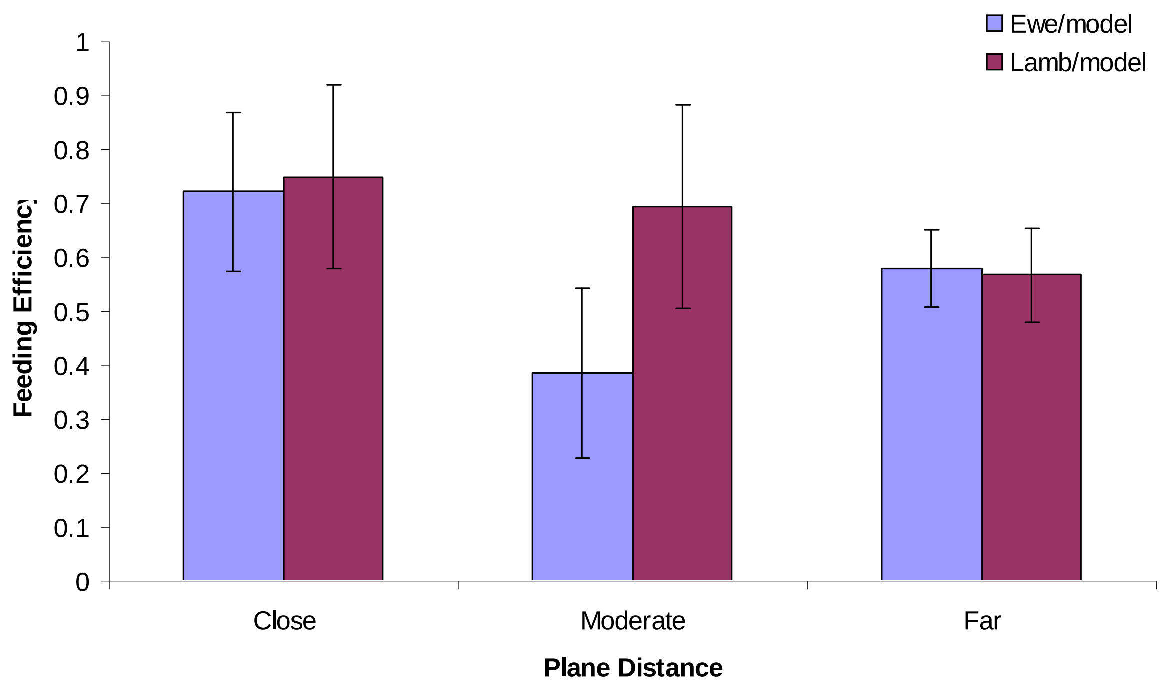


Figure E.36. Mean (+SE) feeding efficiency of Dall's sheep during scan sampling during overflights by small civilian single engine aircraft grouped by proximity: 1) close = aircraft lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=9 for ewe model and *n*=6 for lamb model); 2) moderate = aircraft lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=9 for ewe model and *n*=5 for lamb model); 3) far = aircraft higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=31 for ewe model and *n*=22 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

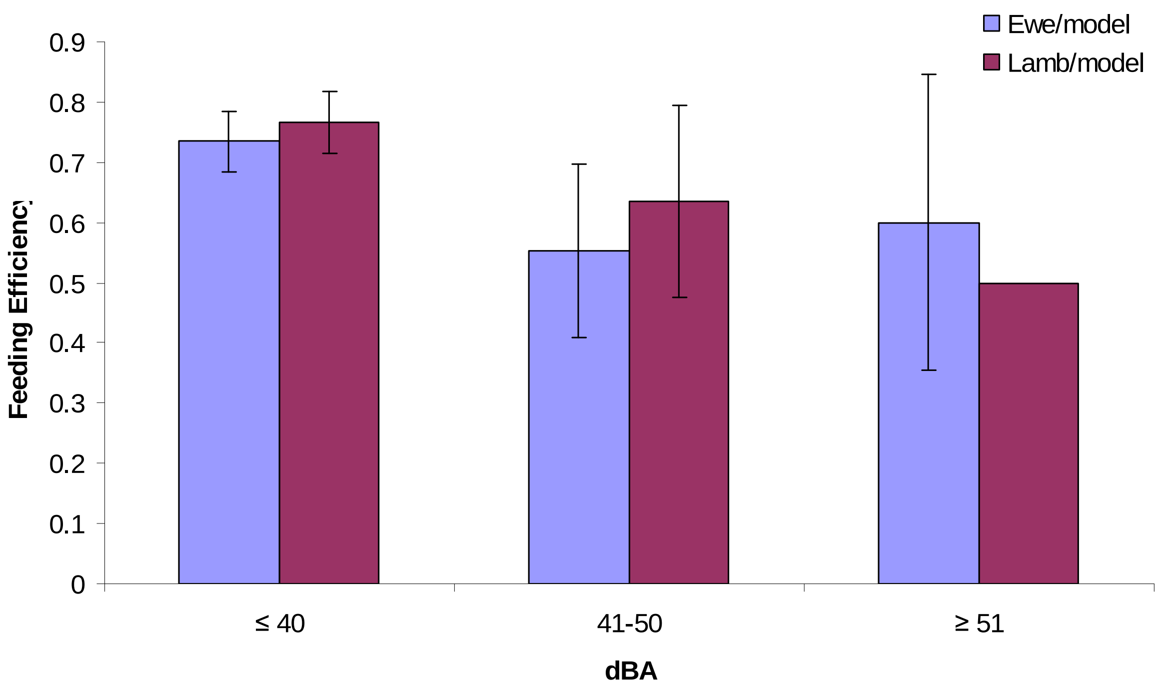


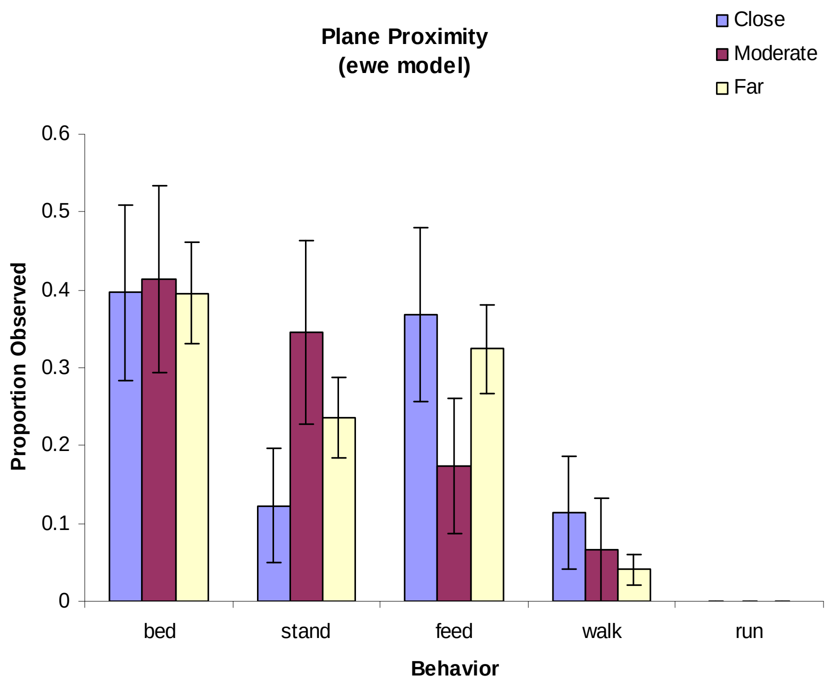
Figure E.37. Mean (±SE) feeding efficiency of Dall's sheep during scan sampling during overflights by small civilian single engine aircraft grouped by 2 minute mean L_{eq} (dBA): 1) ≤ 40 dBA (*n*=51 for ewe model and *n*=42 for lamb model); 2) 41 – 50 dBA (*n*=11 for ewe model and *n*=8 for lamb model); and 3) ≥ 51 dBA (*n*=5 for ewe model and *n*=2 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

Table E.6. Summary of MANCOVA results examining factors affecting the behavior of Dall's sheep (percent bedding, standing, feeding, walking, and running) including proximity and sound level (2 min. mean L_{eq} [dBA]) of overflights by small civilian single engine aircraft during field sessions in 2000 and 2001. Two data sets were considered. One model was examined without considering the presence of lambs, and a second model (restricted to May, June and July) included lambs in the analysis. Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska.

Dependent Variable	Independent Variable*	*d.f.*	*F*	*P*	Partial eta squared
Behavior (ewe/sound model)	Rock	3	2.178	0.117 [a]	0.214
	Ewe	3	4.022	0.019	0.335
	Proximity	6	0.526	0.786	0.062
	L_{eq} (dBA)	3	1.396	0.268	0.149
	Site	3	2.206	0.113 [a]	0.216
	Year(site)	6	2.586	0.030 [a]	0.244
	Sequence(year(site))	24	1.027	0.447	0.252
Behavior (lamb/sound model)	Rock	3	2.695	0.086 [a]	0.366
	Ewe	3	4.719	0.018 [a]	0.503
	Lamb	3	0.769	0.530	0.141
	Proximity	6	1.325	0.279	0.221
	L_{eq} (dBA)	3	1.233	0.335	0.209
	Site	3	2.733	0.083 [a]	0.369
	Year(site)	3	2.710	0.085	0.367
	Sequence(year(site))	9	1.360	0.244	0.220

* Independent variables used in model were: 1) distance from steep rocks; 2) number of ewes in group; 3) number of lambs in group; 4) proximity of overflight to sheep; 5) sound level (2 minute mean L_{eq} [dBA]); 6) study site; 7) year nested within study site; and 8) year nested within study site nested within date sequence.

[a] Interactions between independent variables were assumed if the significance ($P \leq 0.05$) of an independent variable differed when comparing Type III and Type I sum of squares.



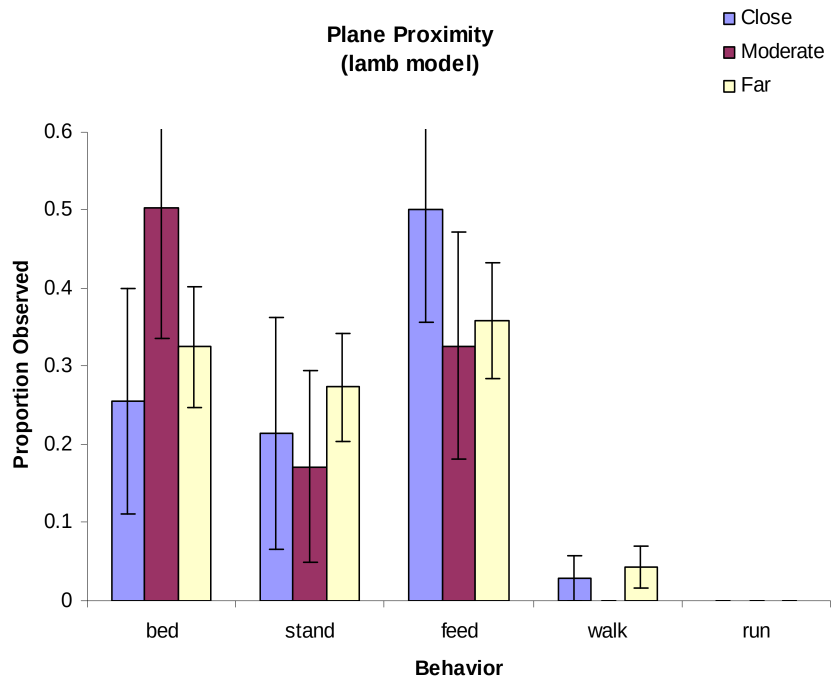


Figure E.38. Mean (+SE) behavior of Dall's sheep during scan sampling during overflights by small civilian single engine aircraft grouped by proximity: 1) close = aircraft lower than 1,500 m AGL and within 1.6 km horizontal distance from sheep (*n*=15 for ewe model and *n*=7 for lamb model); 2) moderate = aircraft lower than 1,500 m AGL and between 1.6 and 3.2 km horizontal distance from sheep (*n*=15 for ewe model and *n*=8 for lamb model); 3) far = aircraft higher than 1,500 m AGL and greater than 3.2 km horizontal distance from sheep (*n*=44 for ewe model and *n*=28 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

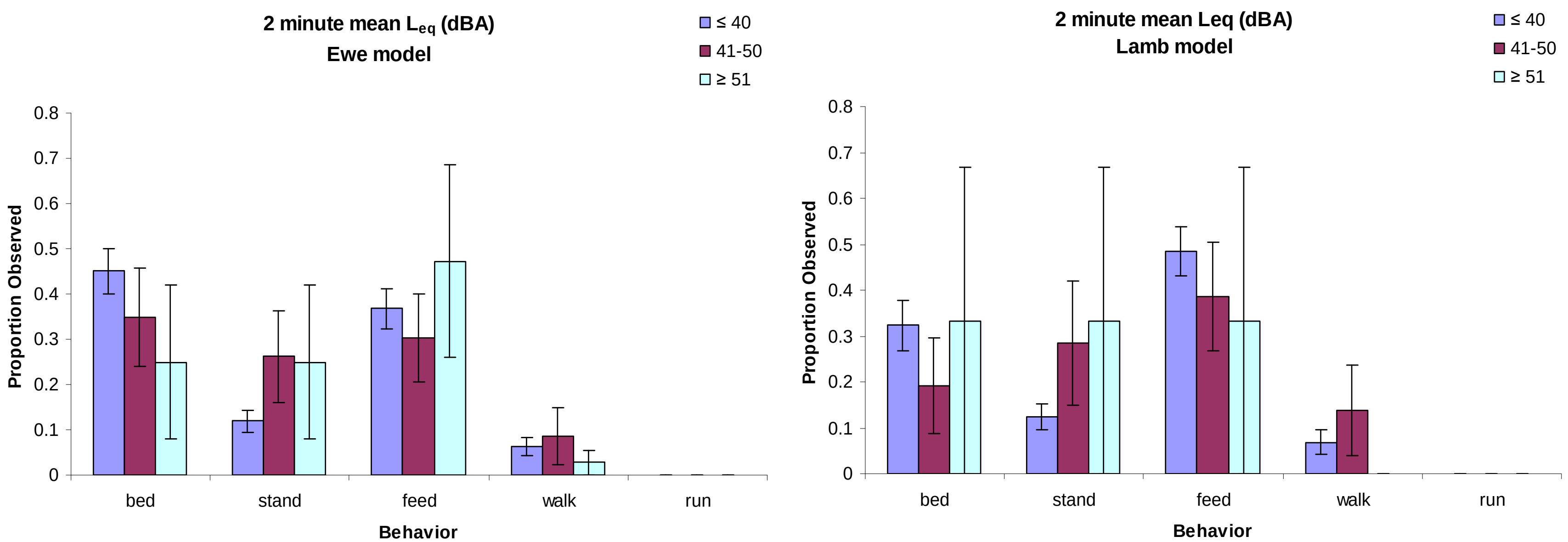


Figure E.39. Mean (±SE) behavior of Dall's sheep during scan sampling during overflights by small civilian single engine aircraft grouped by 2 minute mean L_{eq} (dBA): 1) ≤ 40 dBA (*n*=77 for ewe model and *n*=53 for lamb model); 2) 41 – 50 dBA (*n*=16 for ewe model and *n*=10 for lamb model); and 3) ≥ 51 dBA (*n*=6 for ewe model and *n*=3 for lamb model). Observations were made at 2 study sites in the Yukon-Tanana Uplands of Interior Alaska. Observations were made between late February and early August for the ewe/model and a subset of this data (observations between May and August) was used for the lamb/model.

APPENDIX F. Power Analysis for Usage Variables

Here a power analysis is conducted to determine an adequate sample size for detecting overflight effects in sheep home range size, average daily distance traveled, and vegetation type usage. Statistical power is the probability of detecting effects given they are present in the sampled population. If certain effects are present, they can always be detected with high probability by increasing the sample size of observed individuals. In some cases, however, the sample size often has to be increased to an unattainable size in order to detect small effects in the sampled population. Although no significant jet overflight effects were observed, the number of collared sheep is relatively low; this implies that sample size may be too low to have a high probability of detecting them. Therefore, a power analysis was performed to determine the number of sheep that would have to be collared to detect sortie effects at least as large as what was observed.

Three models used were examined for their ability to detect present sortie effects: the MANOVA model for determining sortie effects on vegetation type usage and the two ANOVA models for examining sortie effects on average daily distance traveled and home range size over each 2 week sequence. For the 2 ANOVA analyses, exact power calculations were made, however, due to the complexity of the MANOVA test statistic sampling distribution, simulations were necessary to approximate the power of the vegetation usage analysis.

In both of the ANOVA models the "effects" parameterization was used for the power analysis. For a simple 2 covariate model, the effects parameterization is given by

$$Y_k = a_i + b_j + c_{ij} + \varepsilon_k,$$

where Y_k is the response variable individual $k = 1,\ldots, n$. The parameters a_i and b_j represent "main effects" and c_{ij} represents an "interaction effect" for $i = 1,\ldots, I$ and $j = 1,\ldots, J$, and ε_k represents an error term for individual k, usually normally distributed.

Parameters are usually estimated using the least squares matrix equation

$$\mathbf{B} = (\mathbf{X'X})^{-1}\mathbf{X'Y},$$

where **B** is the vector of parameters, **X** is the design matrix filled with indicator vectors for each effect parameter (see Neter et al. 1996, chapter 11) and **Y** is the vector of individual observations. The model statement, the usual type of hypothesis test is of the form

$$H_0: b_1 = b_2 = \ldots = b_J = 0;$$

that is to say, the second covariate has no effect on the response variable. The test statistic used to test this type of hypothesis is the F statistic given by

$$F = \frac{\left(SSE_r - SSE_f\right)/df_1}{SSE_f / df_2},$$

where *SSE* is the error sum of squares. The subscripts *f* and *r* refer to the *SSE* values when the full model is used and when the reduced model (without the covariate being tested) is used. The *df* values are degrees of freedom. Both df_1 and df_2 are calculated based the ranks of the matrices used to calculate the numerator and denominator of the *F* ratio (see Hocking 1996).

The *F* ratio has a central *F*-distribution with df_1 and df_2 degrees of freedom if the null hypothesis is true; all of the tested parameters are in fact equal to 0 in reality. Therefore, the null hypothesis is rejected if the calculated *F* ratio exceeds the 95th percentile of the central *F*-distribution. This gives a Type I error rate of 5%. If the null hypothesis is in fact false, however, the *F* ratio has a "non-central" *F*-distribution with non-centrality parameter λ. Hocking (1996) provides a formulation for λ. Under the assumption of normal errors, the power of the test, which is equal to the probability that one rejects the null hypothesis when it is false, is equal to

$$\Pr\{F > F(0.95, df_1, df_2)\},$$

where the random variable *F* has a non-central *F*-distribution with df_1 and df_2 degrees of freedom and $F(0.95, df_1, df_2)$ is the 95th percentile of the corresponding central distribution. This can be calculated directly from the cumulative distribution function of the non-central *F*-distribution.

The ANOVA models used for the analysis of average daily movement and home range size represent an incomplete design when all 2-way interactions of the covariates, study area, year, and sequence, are included. This is due to the fact that not all sequences we're observed in every year. The implication of this is that the parameters estimated with the least squares equation are not unique as the inverse of the **X'X** matrix does not exist. Therefore, the effects parameters do not have a well defined interpretation. So, only sample size adjustments were examined for their effect on power to detect sortie effects.

To examine the sample size effects on the power to detect sortie effects sample size was iteratively increased and the power was calculated. Power calculations were made by assuming the estimated cell means from the least squares predictions were the true population means. Sample sized was then increased by the addition of 1 observation to each year*sequence that was observed in the study. This would result from the addition of 2 collared sheep per year, one in each study area. Sample size was increased in this manner in order to keep the dimension of the model parameters the same. If observations were added to year*sequence cells where no observations were made adds additional model degrees of freedom. Since absence of observations in a certain cell is due to inability to make the observations at that time we felt that it was unrealistic to add observations where they could not have been made.

Figure 1 illustrates the power curves for average daily distance and home range size analyses, as well as the MANOVA vegetation type use analysis discussed later. The curves show that the addition of 10 observations for each year*sequence observed in the study (indicated with the vertical line) will result in a power of approximately 0.82 for detecting the sortie effect on average daily distance traveled and 0.77 for detecting sortie effects on home range size. This indicates that it is probably necessary to double the number of collared sheep to detect sortie effect as large as what was estimated with the given sample.

The same procedure was followed for the power analysis of the MANOVA model used to investigate sortie effects on the vector of vegetation type usage. Parameters are estimated with the same least squares equation, but, now the set of parameters **B** is a matrix. A common test statistic is based on the likelihood ratio

$$\Lambda = |\mathbf{E}| \,/\, |\mathbf{H}+\mathbf{E}|,$$

where $|\cdot|$ represents the determinant of a matrix, **E** is the sum of squared error matrix for the full model, **H** is the difference is error sums of squares between the reduced model and the full model. An F statistic is then calculated from this ratio (see Johnson and Wichern 1992, Chapter 7 for complete description of the F statistic and associated degrees of freedom df_1 and df_2). Unfortunately, under the alternative hypothesis the non-centrality parameter is difficult to calculate. Therefore, a simulation is used to approximate the power calculation stochastically. For each step in the addition of observations described previously, a simulation was performed to determine $\Pr\{F > F(0.95, df_1, df_2)\}$.

When sample size was increased the predicted values were calculated based on the estimated values from the full model calculated with the real data. These parameter values were taken for “reality” as with the ANOVA models. For each predicted value a multivariate normal error term was simulated with the variance-covariance matrix calculated from the real data. This was repeated 1000 times and the proportion of times that the sortie effects were significant were used to approximate the power for the given sample size. Again, Figure 1 illustrates the power for the multivariate test for sortie effects on the vector of vegetation type usage. With the addition of 10 observations per year*sequence, the power for detecting sortie effects is approximately 0.78.

Overall, it appears that in order to have a reasonable chance of detecting sortie effects given they are at least as large as what was observed with the current sample, the number of collared sheep should be doubled at minimum. Therefore, the lack of significant sortie effects in the present analysis should not be taken for absence of any sortie effects. The current sample size is not large enough to detect significant sortie effects that are as large as the estimated effects.

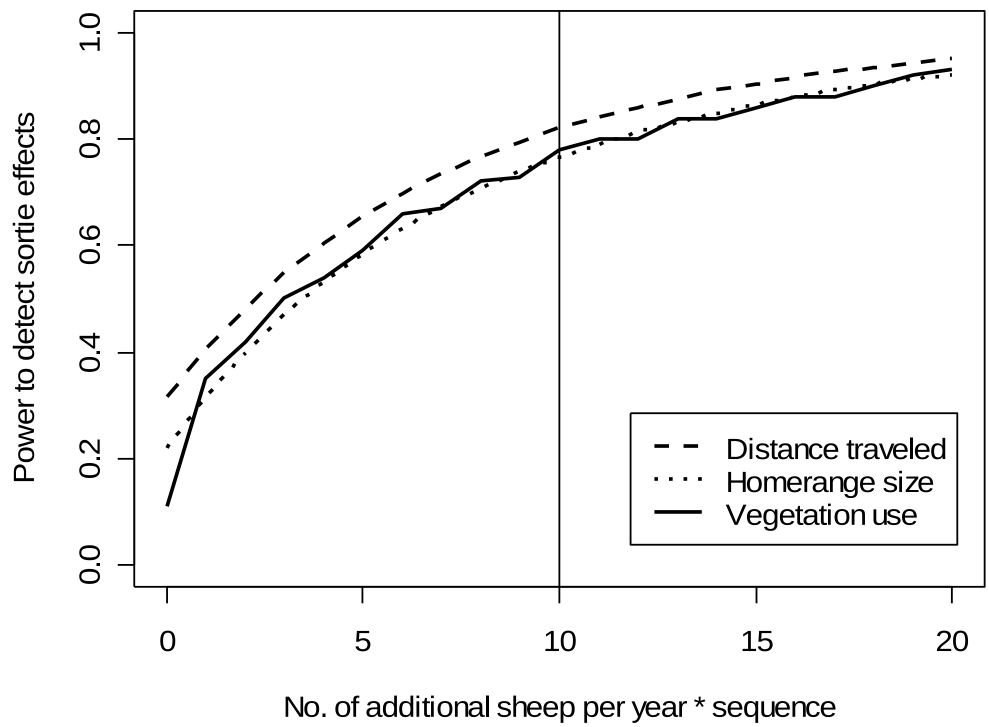


Figure F.1. Power curves for detecting sortie effects. Average daily distance traveled and home range size power curves were calculated exactly. Power for sortie effects on vegetation type usage was simulated. The vertical line represents a sample size twice as large as the current data set.