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Dall Sheep Use of Areas of Critical Environmental Concern in the Utility Corridor Management Area, Alaska

Tim Craig and Paul Leonard

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Cover Photo

A Dall sheep ewe and two lambs near the Dalton Highway at the head of the Atigun River valley. This and other report photographs by BLM/Tim Craig.

Author

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Abstract

From summer 2000 through summer 2006, we sporadically searched for Dall sheep (*Ovis dalli*) and/or evidence of their habitat use in 5 Areas of Critical Environmental Concern (ACECs) on Bureau of Land Management-administered lands in the eastern Brooks Range of northern Alaska. The purpose of our work was to determine (1) when sheep use the ACECs, (2) how many sheep use the ACECs, and (3) which areas within the ACECs were of special importance to sheep.

We found that sheep used all 5 ACECs year-round. We determined that lambing takes place in, or very near, all of the ACECs, and that ewes selected habitat near escape terrain and foraging areas to lamb. In each ACEC, sheep occupied locations with shallow snow, such as windswept ridges or south-facing, steep slopes during the winter. We were not able to accurately estimate the sheep population in the ACECs during this season because of the difficulty in detecting white sheep in the snow. However, the number of tracks we found suggested that far fewer sheep occupy the ACECs in the winter than in the summer.

The highest number of sheep we observed during the summer on any one survey was in the Snowden Mountain ACEC (N = 173), and the lowest numbers were in the Galbraith Lake and West Fork Atigun ACECs (N = 6 and 8, respectively). Generally, we found sheep at high elevations during the summer and in selected habitat where vegetation was low and sparse, such as the earth cover classes Low Shrub, Low Shrub – Lichen, Dwarf Shrub, Dwarf Shrub – Lichen, and Rock/Gravel. The relative density of tracks during the winter indicated that the Snowden Mountain and Poss Mountain ACECs hosted the greatest number of sheep during these months, while the West Fork Atigun and Nugget Creek ACECs held the least.

Sheep were observed 1212 times in the ACECs during our surveys, but we made many more observations of sheep immediately outside ACEC boundaries. In addition, we located previously unreported potential sheep licks in the Snowden Mountain and the West Fork Atigun ACECs.

Our results indicate that the sheep population within the ACECs may fluctuate annually without known causation, a phenomenon that is reflected in surveys of the greater sheep population elsewhere in the Brooks Range. The population structure in the ACECs is within the ranges of both historic and contemporary values determined for sheep elsewhere in the Brooks Range. The data collected during our work can be used for future population comparisons and as a baseline for sheep habitat use within the ACECs.

Acknowledgments

We thank Marty Webb for his expert service as a pilot and as an observer. Cindy Hamfler and Jon Syder flew several habitat survey flights. Erica Craig provided advice on habitat analyses. Richard Kemnitz provided helicopter time for our survey, and Kyle Joly, Craig McCaa, Cindy Hamfler, and Jim Herriges offered editorial comments on the manuscript.

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Introduction

The Bureau of Land Management (BLM) is responsible for management of public lands around the Dalton Highway and adjacent Trans-Alaska Pipeline System between mileposts 56 and 300 on the Dalton Highway. This area is managed under the guidance of the BLM's Utility Corridor Resource Management Plan (BLM 1989), which was implemented in 1991. The BLM unit that administers this land is the Central Yukon Field Office of the Fairbanks District Office.

The Federal Land Policy and Management Act of 1976 (FLPMA) provides for the establishment of Areas of Critical Environmental Concern (ACECs) on BLM-managed public lands. FLPMA defines an ACEC as an area "within the public lands where special management attention is required (when such areas are developed or used or where no development is required) to protect and prevent irreparable damage to important historic, cultural or scenic values, fish and wildlife resources, or other natural systems or processes…" The Utility Corridor Resource Management Plan delineated 5 ACECs totaling 42,005 ha specifically to protect Dall sheep (*Ovis dalli*) habitat and other resources.

Dall sheep (hereafter referred to as "sheep" in this report) are found throughout the Utility Corridor where appropriate habitat occurs, but the sheep density is highest in the northern third of the corridor. The public has a great appreciation for mountain sheep (Summerfield 1974). This interest includes the recreational viewing of sheep and their harvest under both sport and subsistence regulations. One measure of this interest is the harvest of 120 to 134 rams by hunters in the general area from 1998 to 2000 (Stephenson 2002). In addition, visitors to the Arctic Interagency Visitor Center in Coldfoot commonly comment favorably about sightings of sheep when they travel through the area (Lisa Jodwalis, BLM, pers. comm.).

The sheep population in portions of the eastern Brooks Range declined during the early 1970s and then rebounded in the 1980s (Stephenson 2002). Another steep population decline occurred in the early 1990s (Brubaker and Whitten 1998; Lenart 2002; Lawler 2004), this time in both the eastern Brooks Range and the Alaska Range. The reason for the declines, up to 40% in portions of the eastern Brooks Range, is thought to be weather-related; the declines correlate with winters of deep snow during this time period (Stephenson 2002). The Alaska Range population rebounded during the relatively mild winters during the late 1990s, while the Brooks Range sheep numbers did not. Therefore, other limiting factors are probably controlling recovery of the sheep population in this area (Steve Arthur, Alaska Department of Fish and Game, written comm.).

In 1993, the Alaska Department of Fish and Game (ADFG) established a conservative management approach for sport sheep hunting throughout the area by establishing a "full-curl-ram-only" regulation. This has helped improve the population structure of sheep in the Eastern Brooks Range by increasing the number of breeding-age rams (Stephenson 2002), although the population size has not increased.

In addition to the sport hunts administered by the ADFG, the BLM administers 2 Federal Subsistence sheep registration hunts in the Utility Corridor. Both of these hunts are within the Dalton Highway Corridor Management Area (the State designation for an area extending 8 km (5 miles) from either side of the Dalton Highway). One hunt occurs to the south of Atigun Pass and one to the north. The harvest limit for these hunts is one ⅞-curl ram per year per hunter. Recent harvest reports from these hunts show that the reporting hunters took 2 to 5 sheep annually for subsistence use and that most of these sheep were killed in the hunting unit south of Atigun Pass. Five to seven unsuccessful hunts were reported annually as well. However, because the same hunter could participate in both hunts, double reporting might have occurred if a person was successful in one hunt and not in the other.

Other researchers have conducted surveys of sheep and their habitat on BLM-administered public land in the Utility Corridor and on adjacent lands administered by other entities (Summerfield 1974; Daum 1982; Jakimchuk et al. 1984; Stephenson 2002). However, to our knowledge, no one

has published inventories of sheep habitat or sheep use specifically in BLM ACECs in the Utility Corridor.

Declining sheep populations throughout northeast Alaska in the last half-century have increased the importance of identifying and monitoring significant sheep habitats. Such research not only helps land managers assess the efficacy of management actions designed to protect sheep, but it provides data that can be used to modify and improve those efforts.

Study Area

Our study occurred in the 5 ACECs established for the protection of sheep habitat in the Brooks Range (Figure 1). Three of these ACECs are located on the southern slopes of the Brooks Range: Poss Mountain (3237 ha), Nugget Creek (1335 ha), and Snowden Mountain (11,331 ha). Poss Mountain and Nugget Creek lie on opposite sides of the Middle Fork Koyukuk River valley. The Snowden Mountain ACEC is about 35 km north of these ACECs within the Dietrich River drainage, a major tributary of the Middle Fork Koyukuk River. These ACECs and nearby mountain valleys host a variety of largely undisturbed habitats native to interior Alaska, including low shrub communities (dominated by *Salix* spp., *Betula* spp. and *Vaccinium* spp.), riparian areas (dominated by *Picea glauca*), patchy spruce (*P. glauca* and *P. mariana*) bogs, and deciduous forests (dominated by *Populus tremuloides*, *P. balsamifera*, and *Betula papyrifera*). At higher elevations, habitat is predominated by treeless dwarf shrub communities and sparsely vegetated (*Carex* spp. and forbs) escarpments and scree.

The remaining 2 ACECs are located on the north slope of the Brooks Range. The West Fork Atigun ACEC (3440 ha) is in the upper Atigun River drainage while the Galbraith Lake ACEC (22,662 ha) is on the northern edge of the mountain range near the Arctic Foothills physiographic province (Wahrhaftig 1965). These study sites are largely covered with treeless, dwarf shrub vegetation communities. Vertical escarpments and scree, sparsely vegetated with *Carex* spp. and forbs, are predominant habitat features in the West Fork Atigun and Galbraith Lake ACECs.

The topography in the general area of all 5 ACECs is mountainous. Most are bordered by broad, glacier-carved mountain valleys that are fed by steeply incised tributaries. Elevations within the ACECs range from 600 m in the bottoms of the rugged side-canyons to nearly 2000 m on the nearby jagged peaks. The lithic material in the study areas is predominated by Precambrian and Paleozoic limestone/marble, quartzite, schist, conglomerate, sandstone, and shale (Brosgé and Reiser 1964; Brosgé et al. 1979).

An arctic climate characterizes all of the ACECs. The warm temperatures and continuous daylight of summer contrast sharply with the extreme cold temperatures and abbreviated light of winter in the study area. The annual changes between summer and winter can be abrupt at this high latitude; spring and fall are often abridged. The average July temperature in Wiseman, Alaska, the village nearest the study area, is 14 °C while the average temperature in January is –27 °C (Natural Resources Conservation Service, Anchorage, written comm.). Annual precipitation at nearby Bettles, Alaska, averages about 35 cm (National Weather Service data).

Methods

Surveys and observations were conducted in the ACECs during various seasons from 2000 to 2006. Techniques used to determine habitat use and population size of sheep in the ACECs are detailed below.

Summer Habitat Use Surveys

Although snow can be present at any time of the year at high latitudes, we classified as "summer" surveys those that were conducted during the months that are most often snow-free (May–August). Summer habitat surveys were conducted in helicopters (Eurocopter AS350 AStar and Bell 206B) and fixed-wing aircraft (Bellanca Scout or Piper PA-18). Logistical challenges caused us to conduct surveys opportunistically, resulting in uneven spatial and temporal coverage among ACECs. The Galbraith Lake and West Fork Atigun ACECs, the 2 northernmost units, were each visited 2 times, the Nugget Creek ACEC 4 times, and the remaining 2 ACECs 3 times

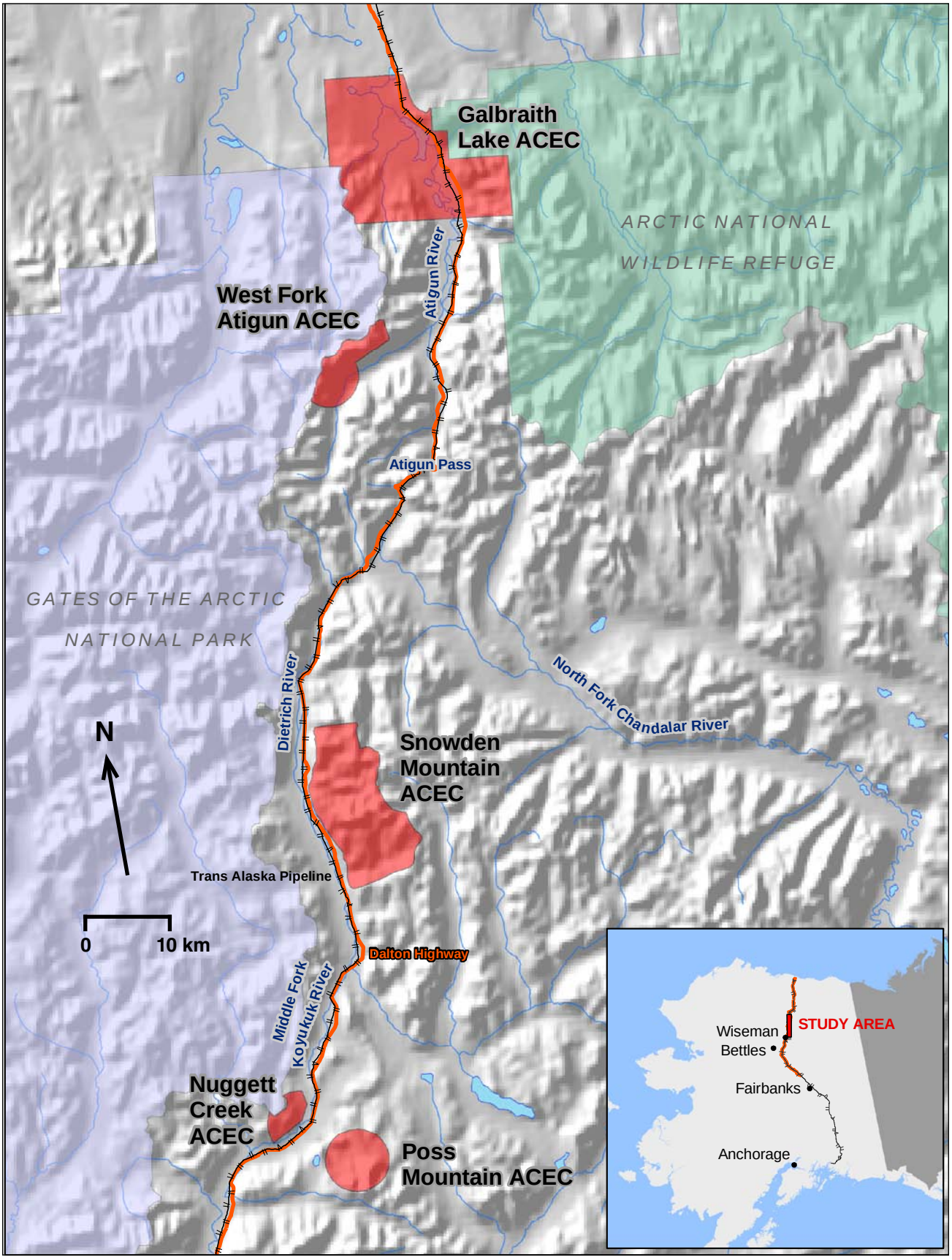

Figure 1. Location of the 5 ACECs within the Utility Corridor Management Area, Alaska.

each. We collected no data in 2001 due to lack of funding. In total we spent about 530 min surveying the ACECs during summer months. We did not record the time spent conducting population surveys within individual ACECs because summer surveys were part of a continuous survey of the larger area.

During fixed-wing surveys the pilot and 1 passenger made observations; during most helicopter surveys the pilot and 2 passengers made observations. Observers recorded geospatial data on 1:63,600 U.S. Geological Survey topographic maps or used a handheld Global Positioning System (GPS) unit to mark electronic waypoints. An exhaustive survey of the sheep populations in the ACECs was not made during these flights. To minimize disturbing animals and potentially causing abandonment of habitat (Lawler et al. 2005), we avoided approaching sheep closely and did not hover over bands longer than necessary. As a result, we classified sheep into only 2 age/sex categories: (1) ewe/lambs (includes ewes, lambs, and rams that were indistinguishable from ewes, i.e, usually less than half-curl) and (2) rams half-curl or larger.

Habitat features like mineral licks have been shown to be very important components of sheep habitat (Heimer 1973). Licks provide sheep with nutrients and facilitate social interactions among individuals (Jakimchuk et al. 1984). Therefore, we recorded all licks observed during our flights. When sheep were not present, we identified licks based on the presence of multiple trails leading to areas where disturbed soil was obvious (Daum 1982).

We also recorded locations where we observed ewes with newborn lambs in late May and early June, the reported peak of lambing in the area (Daum 1982). It is assumed for this report that these animals were spotted near natal sites.

Winter Habitat Use Surveys

The annual movement of sheep from winter to summer range is related to decreasing snow depth and increasing temperatures (Jakimchuk et al. 1984). Therefore, we surveyed the 3 southernmost ACECs via fixed-wing aircraft (Bellanca Scout or Piper PA-18) during early spring 2003, when snow depths for that winter were at their maximum extent (exceeding 70 cm on level ground). In 2003 and 2004 we also surveyed the 2 northernmost ACECs in late September (snow depth, 30+ cm), after sheep were known to have moved back to winter range in the Atigun River valley (Summerfield 1974). The purpose of these flights was to determine if sheep over-winter in the ACECs. We flew approximately 275 min to survey the areas. We did not attempt to count individuals during these surveys because of the difficulty of seeing sheep in a snow-covered landscape. Rather, we searched for and recorded all sheep tracks within the ACECs (Figure 2).

We recorded observations in 2 categories that we could distinguish from the air: (1) tracks of sheep bands of less than 5 animals and (2) tracks of bands of more than

Figure 2. These barely discernible Dall sheep tracks (indicated by arrows) illustrate one of the challenges of winter sheep observations in the Brooks Range. Photo taken in Poss Mountain ACEC.

5 animals. Depending on snowfall and wind, sheep tracks can remain visible for long periods. Consequently, we were not able to definitively determine the winter sheep population in the ACECs, although we were able to estimate habitat use from the presence of tracks that appeared to be of similar ages. The meandering nature of the tracks, which were usually localized on wind-blown ridge tops and steep, south-facing rocky slopes, prevented us from attempting to map complete usage areas based on the tracks we observed. We did record any sightings of sheep we made during these flights. In addition, we included some opportunistic observations we made from vehicles on the Dalton Highway.

Population Surveys

From 2002 through 2006, the ADFG inventoried sheep in the eastern Brooks Range in an effort to monitor the sheep population in the general area. Its survey data are included in the *Results and Discussion* section of this report. The BLM helped fund the surveys in 2002, 2003, and 2006. Most of the ADFG's survey effort was concentrated in a large survey unit located in the Chandalar River drainage, east of the Dalton Highway. This unit included the Snowden Mountain ACEC and was near the Poss Mountain ACEC. As a result, the Snowden Mountain and Poss Mountain ACECs were surveyed more often than the others, producing uneven population data for the 5 ACECs. In addition, the ADFG's 2002 and 2003 surveys included location data on sheep sightings that occurred in the Snowden Mountain ACEC. In 2006 ADFG researchers recorded this information for all of the ACECs. We used these data along with our own observations in the analyses of sheep habitat preferences.

In conducting these surveys, the ADFG employed its typical techniques for surveying sheep (Whitten 1997). In short, researchers used fixed-wing, 2-place aircraft (Piper PA-18) with both the pilot and the passenger acting as observers. The ADFG mostly conducted surveys when winds were calm and visibility was good. However, conditions sometimes changed during this effort. The ADFG aborted surveys when environmental conditions became unsafe for flying or appreciably impeded observations. Researchers attempted to locate all sheep within units during each survey. However, extensive cliffs and rockslides complicated observations in some parts of the ACECs and reduced survey accuracy by an unknown factor. The ADFG flew surveys along contour lines in the ACEC, and on most flights, researchers recorded the locations of sheep via the aircraft's GPS. Sheep were classified into 4 age/sex categories: (1) ewes or ewe-like (includes rams that were indistinguishable from ewes, i.e., usually less than half-curl), (2) lambs-of-the-year, (3) sub-adult rams (half-curl to full-curl rams), and (4) full-curl and larger rams.

Earth Cover Use Analysis

The earth cover images dataset used in this report was generated from a Landsat sensor image collected 2 July 1999 and 23 June 2001. The earth cover classification incorporated methodology developed by the BLM and cooperators as described in BLM et al. (2003), as well as an existing Alaska Vegetation Classification system (Viereck et al. 1992). Vegetation compositions for the classifications are provided in Appendix A. The classified earth cover grid has a spatial resolution of 30 m. The overall classification accuracy reported in BLM et al. (2003) was 74.6%. For our analysis the overall classification accuracy is assumed to be 100%; the impact of this assumption will not be evaluated. We analyzed sheep habitat preferences by generating random points (1 for every 2 ha of land) in each ACEC and attributing those points to their associated earth cover type. These points were then compared with the observed sheep earth cover use and tested for heterogeneity or independence via a chi-square test. This enabled us to determine if sheep were using earth cover types at the same frequency that they occur in the ACECs. For each ACEC, earth cover classes were combined into 3 categories to perform the chi-square test (see *Results and Discussion*; Table 4). Lumping occurred in instances where we did not observe sheep in a class (All Other), where only one sheep location was recorded and that earth cover class was dissimilar from other classes (All Other), or

where multiple sheep locations were characterized by similar classes (e.g., Low Shrub, Dwarf Shrub, etc.).

Because sheep rams are of particular importance to the public, we focused on their habitat use within each ACEC. To do this, we determined the range of elevation at which all rams were found within the ACECs, buffering observations by 50 m to account for any error associated with the digital elevation model data (e.g., pixel size and any inherent error in the base data) as well as GPS location error. Within the elevation range, we measured the area covered by the 5 earth cover types where rams were most often found, and determined the percent of the total ACEC area that met these criteria.

Results and Discussion

Summary data for the summer, winter, and habitat surveys are presented in Tables 1, 2, and 3. The next section describes our findings for each ACEC and is followed by our general observations, a summary of our findings, and our recommendations for further study.

Table 1. Habitat surveys of Dall sheep and sheep licks observed during the summer in 5 ACECs in the Utility Corridor Management Area, Alaska. *Partial survey

Visit site	Date	Duration	Rams	Ewes/ lambs	Total	Licks
Poss Mountain	28 Jul 2000	10 min	1	15	16	
	28 Jun 2002	19 min		60	60	
	1 Jun 2004	29 min	5	55	60	
	25 Jul 2006	12 min	1	14	15	1
	Subtotal (min)	70	7	144	151	
Nugget Creek	11 Aug 2000	10 min	5	14	19	
	28 Jun 2002	7 min	1	11	12	
	27 Jun 2003	6 min		11	11	
	1 Jun 2004	5 min	8	20	28	
	25 Jul 2006	3 min	9	-	9	
	Subtotal (min)	31	23	56	79	
Snowden Mountain	7 July 2002	57 min	7	158	165	1
	27 Jun 2003*	<5 min	17	11	28	1
	1 Jun 2004	79 min	35	57	92	
	25 Jul 2006	58 min	-	34	34	1
	Subtotal (min)	<199	59	260	319	
West Fork Atigun	26 Jun 2003	20 min	-	2	2	2
	22 May 2004	37 min	-	2	2	
	25 Jul 2006	8 min	-	17	17	
	Subtotal (min)	65	-	21	21	
Galbraith Lake	27 Jun 2003	80 min	-	9	9	
	22 May 2004	85 min	16	113	129	
	25 Jul 2006	39 min	-	0	0	
	Subtotal (min)	164	16	122	138	
	Total	**<530**	**105**	**603**	**708**	**6**

Table 2. Winter surveys of Dall sheep and sheep tracks in 5 ACECs in the Utility Corridor Management Area, Alaska. *Partial survey

Visit site	Date	Duration	Tracks <5	Tracks 5+	Rams	Ewes	Lambs	Total Sheep Spotted
Poss Mountain	25 Apr 2003	18 min	3	5		6		6
	23 Sep 2003*	< 5 min		1	3	7	2	12
Nugget Creek	25 Apr 2003	3 min	1			1	1	2
Snowden Mountain	25 Apr 2003	32 min	7	3		4		4
West Fork Atigun	23 Sep 2003	25 min	1		2			2
	22 Apr 2004	62 min		1		1	1	2
Galbraith Lake	23 Sep 2003	45 min	6		1			1
	22 Apr 2004	90 min	4		5	18		23
Total		**275 min**	**22**	**10**	**11**	**37**	**4**	**52**

Table 3. Summer population surveys of Dall sheep observed by ADFG in 5 ACECs in the Utility Corridor Management Area, Alaska.

Visit site	Date	Duration	Rams	Ewes	Lambs	Total
Poss Mountain	23 Jun 2004	Not recorded	0	26	7	33
	28 Jun 2006	Not recorded	4	22	4	30
Nugget Creek	28 Jun 2006	Not recorded	11	21	3	35
Snowden Mountain	22 Jun 2004	Not recorded	0	59	13	72
	29 Jun 2005	Not recorded	10	119	44	173
	27 Jun 2006	Not recorded	3	75	29	107
West Fork Atigun	11 Jul 2006	Not recorded	2	6	0	8
Galbraith Lake	11 Jul 2006	Not recorded	1	4	1	6
Total			**31**	**332**	**101**	**464**

Poss Mountain ACEC

Summer Use

The Poss Mountain ACEC (Figure 3) is located on the western end of a rugged, mountainous ridgeline and encompasses roughly the west half of Poss Mountain itself. The principal vegetated cover types in the ACEC are Low Shrub and Dwarf Shrub. However, the non-vegetated classification Rock/Gravel comprises over one-quarter of the entire land cover in the ACEC. While the majority of the sheep habitat on Poss Mountain lies outside the ACEC boundary, the ACEC does include an important sheep mineral lick (BLM 1989) as well as nearby important escape terrain on the northwest side of Poss Mountain. Most of the animals we observed during our surveys were either close to this lick or were in the escape terrain (Figure 4).

We surveyed sheep habitat use in the Poss Mountain ACEC once each in 2000, 2002, 2004, and 2006. When we totaled all of the sheep observations from these flights and the

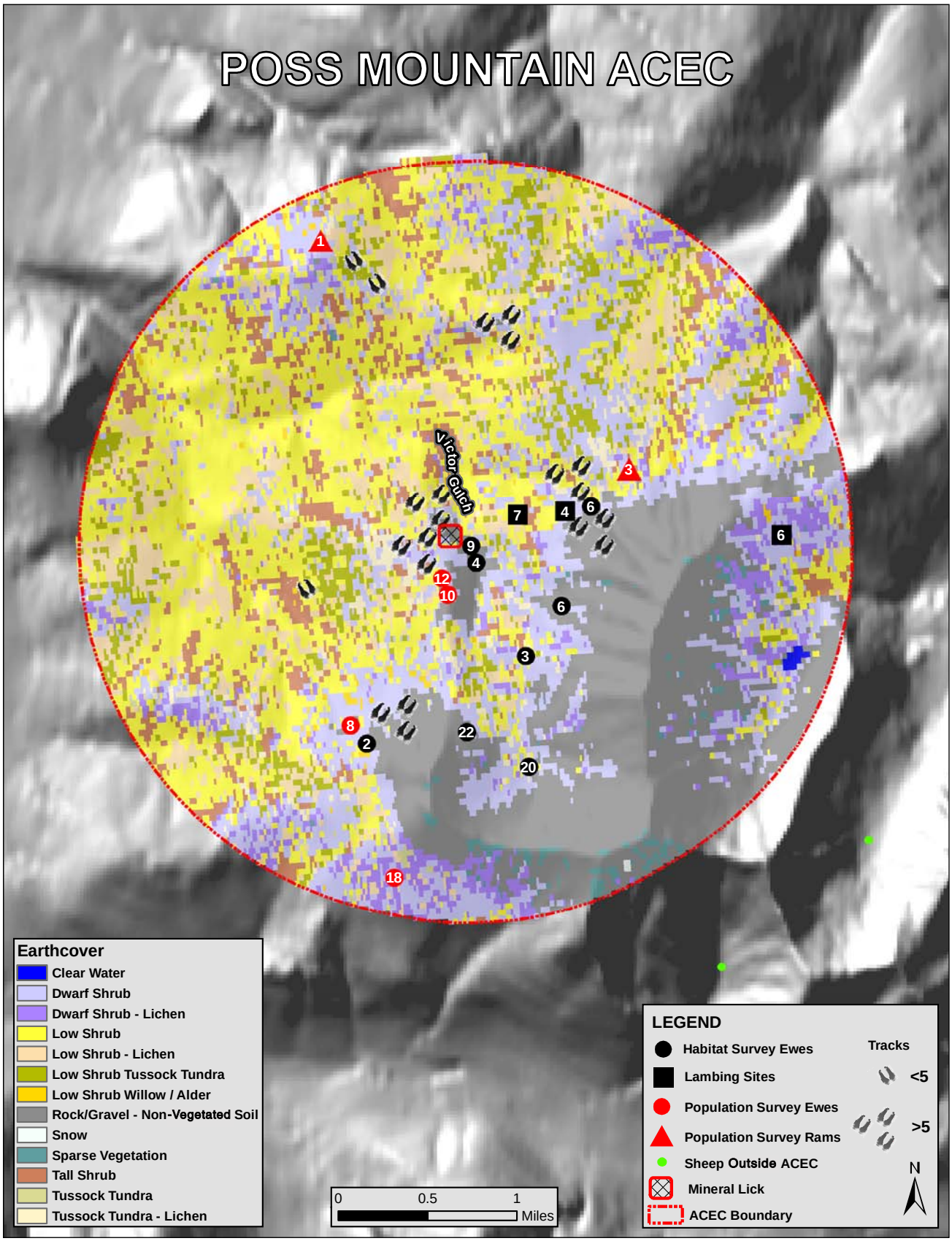

Figure 3. Dall sheep observations in Poss Mountain ACEC, Utility Corridor Management Area, Alaska.

results of the ADFG population surveys, we recorded only 10 rams. These rams, which accounted for 5% of our total sheep observations, were all found in the central and northern half of the ACEC in Low Shrub or Low Shrub – Lichen habitat.

We found 3 lambing areas containing a total of 38 ewes and 17 lambs in the Poss Mountain ACEC in 2004. These sites were in the central and southern portion of the ACEC near the lick and escape cover. The overall ewe:lamb ratio for the ACEC was 4.1:1 (24 lambs/100 ewes).

Winter Use

We found that sheep used the Poss Mountain ACEC during the winter. In fact, winter sheep sign was more concentrated in the ACEC than anywhere else on Poss Mountain and its nearby associated highlands. It appeared from tracks left in the snow that up to 20 animals may have wintered in the ACEC in April 2003. Again, we observed most of the winter use in and around the ACEC near the mineral lick in the head of Victor Gulch and in the nearby escape terrain. On 23 September 2003 we attempted to survey the Poss Mountain ACEC again, but were only able to reach the northwestern edge of the ACEC due to high winds. The only sheep we observed during the flight was a band (7 ewes, 2 lambs, and 3 rams) near the known lick in Victor Gulch. It should be noted that on both of our winter visits, we spotted sheep trails in the snow between the Victor Gulch lick and another heavily used mineral lick northwest of the ACEC in Gold Creek.

Population Surveys

The ADFG surveyed the Poss Mountain ACEC in 2004 and 2006, locating 33 and 30 sheep, respectively, in the ACEC. Again, researchers spotted few rams (0 and 4, respectively). The highest productivity observed during the ADFG flights occurred in 2004 (27 lambs/100 ewes).

Earth Cover Use

Statistical analysis of sheep habitat selection data for Poss Mountain ACEC (Table 4)

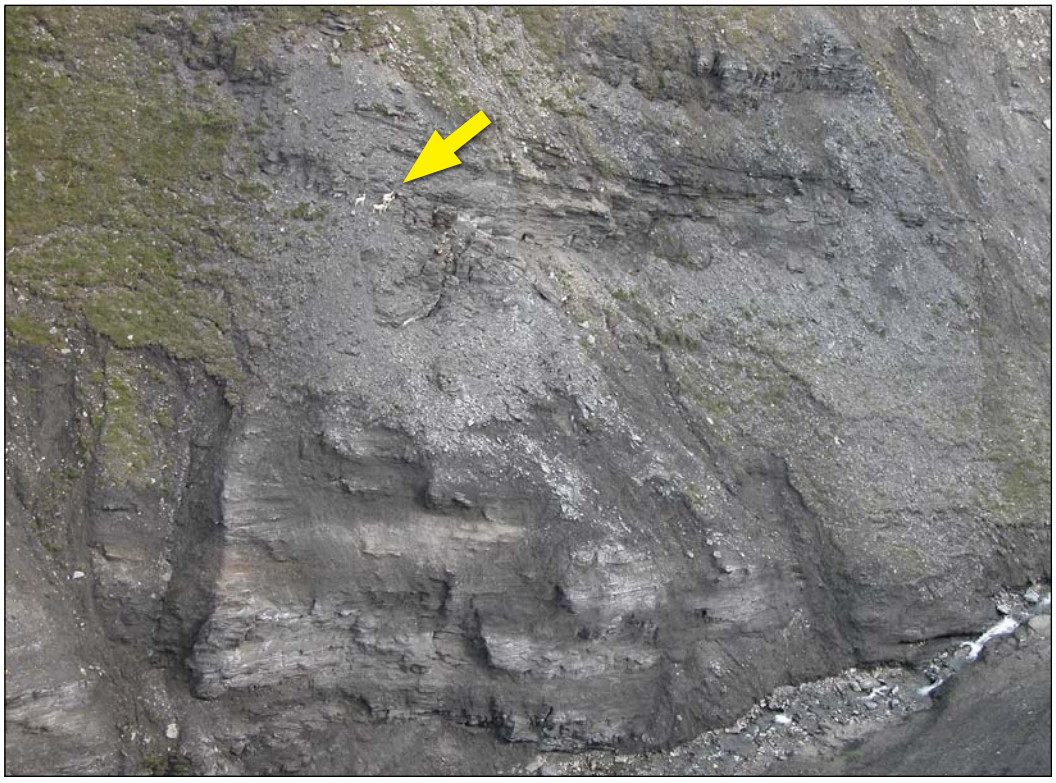

Figure 4. Dall sheep (indicated by arrow) at a mineral lick in Victor Gulch within the Poss Mountain ACEC, Utility Corridor Management Area, Alaska.

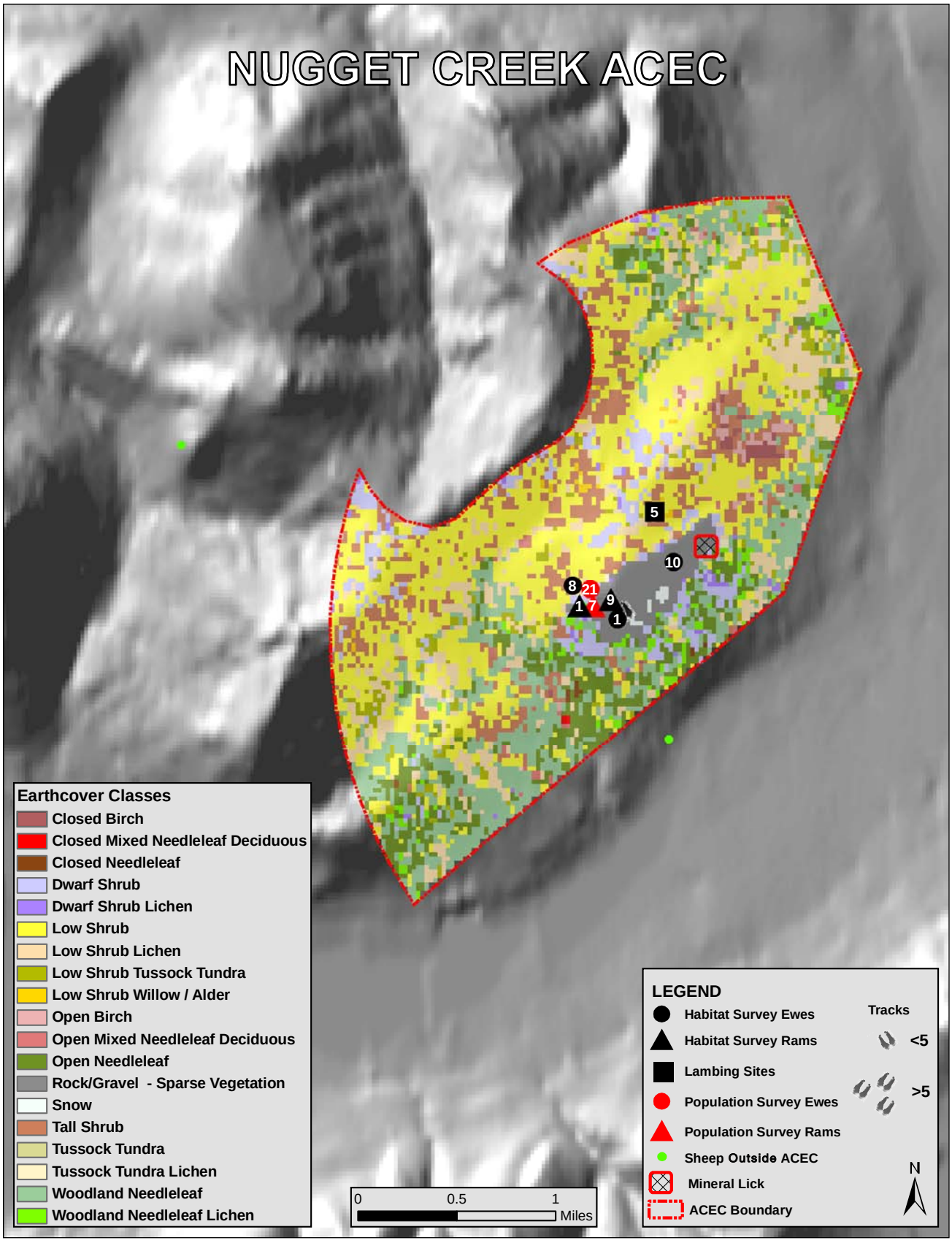

Figure 5. Dall sheep observations in Nugget Creek ACEC, Utility Corridor Management Area, Alaska.

Table 4. Chi-square analysis of earth cover use by Dall sheep in 3 ACECs in the Utility Corridor Management Area, Alaska.

ACEC	Earth Cover	Chi-Square	P Value
Poss Mountain	Low Shrub, Low Shrub – Lichen, Dwarf Shrub	7.25	0.026
	Rock/Gravel		
	All Other		
Snowden Mountain	Low Shrub, Low Shrub – Lichen, Dwarf Shrub, Dwarf Shrub – Lichen, Low Shrub – Willow/Alder	13.66	0.001
	Sparse Vegetation, Rock/ Gravel		
	All Other		
Galbraith Lake	Dwarf Shrub, Dwarf Shrub – Lichen	3.13	0.209
	Rock/Gravel		
	All Other		

revealed that sheep used earth cover classes in the All Other category less than they were available ($\chi^2 = 7.25$, df = 2, $P = 0.026$). The Rock/Gravel class was used more than available, and the Low Shrub categories provided no significant relationship between available and used habitat. Hansen (1996) found that ewes in the Brooks Range fed primarily on forbs and grasses during summer. Because most of our observations were made during the warm season of the year, these results probably demonstrate that animals were selecting habitats that host graminoids (grasses and grass-like plants) and forbs—but that also lie in close proximity to escape cover. We may have flushed sheep into these areas when approaching in the aircraft, and therefore their associated locations fell into the Rock/Gravel earth cover class.

Nugget Creek ACEC

Summer Use

The Nugget Creek ACEC (Figure 5) is the smallest of the 5 ACECs and is essentially comprised of a single, isolated mountain. The topography on the southeast side of this mountain is very steep. Cliffs and scree predominate, providing the only escape cover in the greater area. The north side of the mountain is largely open, gentle terrain covered by graminoids and low shrubs. The dominant earth cover type in these portions of the ACEC is Low Shrub. The juxtaposition of steep escape terrain and the open, foraging habitat on the north side of the mountain creates an island of good sheep habitat in an otherwise inhospitable landscape (Figure 6).

We visited the Nugget Creek ACEC in 2000, 2002–2004, and 2006, successfully locating sheep on each visit (Table 1). Generally, the animals we spotted were foraging in Low Shrub habitat when we arrived, but in most cases, they immediately began moving toward the nearby security habitat when the aircraft approached. We spotted all 3 age/sex classes of sheep in the ACEC. However, because of the limited amount of habitat available in the area, we spotted few sheep in this ACEC during any one visit. The number of sheep observed during habitat surveys ranged from 9 to 28.

We searched for lambing areas in the ACEC in late spring 2004 and found 15 ewes and 5 lambs at one location. This ewe/lamb group was located at the highest elevation in the ACEC and near its most rugged topography.

Figure 6. Dall sheep band (indicated by arrow) in escape terrain in the Nugget Creek ACEC, Utility Corridor Management Area, Alaska. View is toward the north with the Middle Fork Koyukuk River and Dalton Highway in the background.

The same lambing area had been identified by Daum (1982) 20 years earlier, perhaps indicating long-term consistency of lambing in the Nugget Creek ACEC. Escape terrain, known to be a critical component of lambing habitat (Rachlow and Bowyer 1998; Lawson et al. 1982), is particularly important where it occurs near good foraging areas, as it does in the Nugget Creek ACEC.

Ewes and rams in the Nugget Creek ACEC shared very similar territory, and although gender-exclusive groups were sometimes seen, we observed both at overlapping locations. When we tallied sheep observations for all of our surveys, rams accounted for 23.5% of the total observations in the ACEC.

The Utility Corridor Resource Management Plan identified one mineral lick on the steep, rugged southeast side of the mountain in the Nugget Creek ACEC. We did not see sheep using this lick, nor did we detect recent sign of sheep use of the area during our observations. Summerfield (1974) has indicated that mineral licks can be divided into 2 categories. "Primary" licks are used regularly, while "secondary" licks are only used occasionally or when primary licks cannot be accessed for some reason. Perhaps the identified lick in the Nugget Creek ACEC falls in the "secondary" lick category.

Winter Use

Sheep winter habitat is dependent on snow depth, which is related to the physical geography of an area (Heimer et al. 1994). During the winter, sheep seek locations where snow is shallow so they can forage while expending minimal energy (Summerfield 1974). As a result, sheep are sometimes confined to microsites on windswept highlands and/or the lee side of ridges during winter. We found that one small group of sheep used the Nugget Creek ACEC during the winter of 2003 (Table 2). The tracks of these animals were confined to a small area on the brink of a steep escarpment near the single peak in the ACEC.

Population Surveys

Because the Nugget Creek ACEC is so small, each of our visits to the ACEC can be considered a complete census of the area. The largest number of sheep seen during the study period was a mixed band of 35 animals, found

during the 2006 ADFG population survey (Table 3). Later that summer, we conducted a habitat survey in the ACEC and found only 9 rams. The fluctuation in the number of sheep inhabiting the ACEC between the ADFG population survey and our habitat survey a month later indicates considerable movement of sheep in and out of the Nugget Creek ACEC.

Earth Cover Use

Due to the small number of observed sheep locations in the Nugget Creek ACEC, the chi-square analysis offered inconclusive results. However, we were able to draw broad conclusions from data collected in the ACEC. Five of the six unique sheep locations in the ACEC were in the Rock/Gravel classification, which covers the southeast side of the main peak in the ACEC. The other sheep observation was in the Low Shrub habitat on the north side of this mountain. These data echo our observations that sheep foraged in close proximity to escape cover in the ACEC and moved there immediately when threatened.

Snowden Mountain ACEC

Summer Use

The Snowden Mountain ACEC (Figure 7) is the largest of the Utility Corridor ACECs that were established for the protection of sheep habitat on the south slope of the Brooks Range. This ACEC is extremely rugged (Figure 8), with elevations ranging from 600 m to nearly 2000 m. The area, which includes 5 peaks over 1500 m, is incised by 3 third-order tributaries.

We visited this ACEC once each year in 2002, 2003, 2004, and 2006. Compared with the other ACECs, we counted large numbers of sheep during most visits. Analysis of all sheep locations, including the ADFG population survey sightings, revealed that ram and ewe locations were more segregated in this ACEC than in any other, possibly because the large size of the ACEC allowed sheep to occupy separate, yet suitable, habitat. More than 65% of all of the ewes counted were concentrated around the center of the ACEC, while most (70%) of the rams were found in 2 areas along the south-central and southeast borders. During the summer we usually found sheep at high elevations in the ACEC, often at the heads of small side drainages. This finding concurs with reported sheep movements in the Atigun River valley (Summerfield 1974; Jakimchuk et al. 1984).

We found 6 lambing sites in the ACEC in 2004 and counted 44 ewes and 13 lambs in these areas. These observations were all grouped within 2 generalized lambing areas that ADFG identified over 30 years ago (Linderman 1972). The lambing sites were all near steep escape terrain where the prominent earth cover type was Rock/Gravel and Dwarf Shrub – Lichen. The overall ewe/lamb ratio was 3.6:1 (32 lambs/100 ewes).

The Utility Corridor Resource Management Plan and an early ADFG study (Linderman 1974) identified 2 mineral licks in the Snowden Mountain ACEC. We relocated one of these licks but did not find sign of recent sheep use at the other (which was omitted from Figure 7). We did locate 2 new mineral licks based on the presence of sheep trails and soil disturbance at the sites (Figure 9).

Winter Use

We found that more sheep used the Snowden Mountain ACEC than any other during the winter. Heimer et al. (1994) has pointed out that windy areas covered with light, dry snow are important to wintering sheep. Similarly, Summerfield (1974) found that ridge tops are important as sheep wintering areas because they are blown free of snow and are good grazing sites, while Hansen (1996) determined that sheep forage mainly on grasses during the winter. We observed that winter track densities were greatest in the central portion of the Snowden Mountain ACEC and that tracks generally were located on high, windswept ridges and south-facing slopes where snow depth was comparatively shallow and graminoids predominate.

Population Surveys

During June/July 2002–2006 the ADFG surveyed about 201,760 ha (779 square miles) immediately south of the Chandalar River (ADFG field reports, on file with the BLM). The results of these surveys varied by roughly one-third on consecutive years (Table 5), and

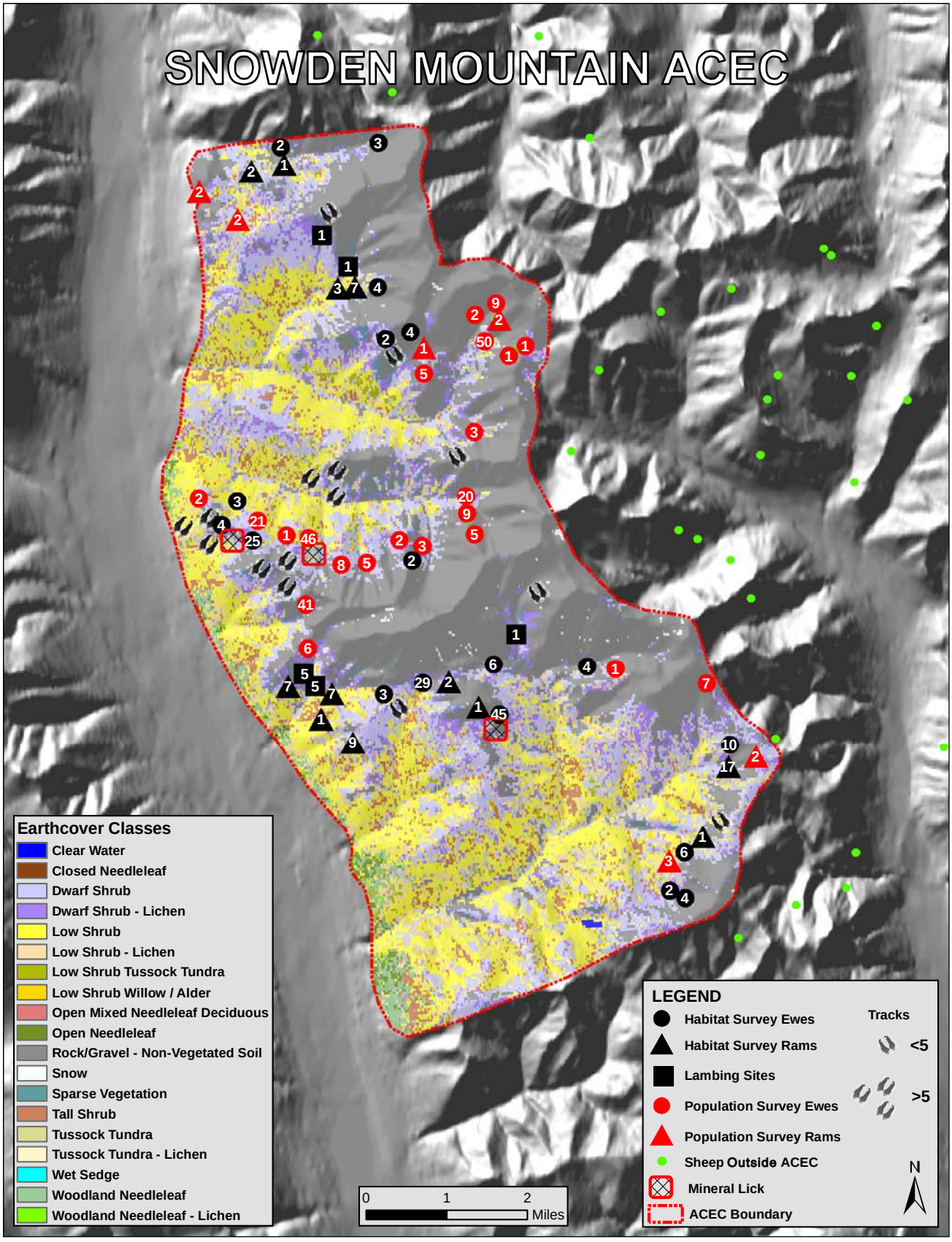

Figure 7. Dall sheep observations in Snowden Mountain ACEC, Utility Corridor Management Area, Alaska.

Figure 8. Rugged terrain on the western side of the Snowden Mountain ACEC, Utility Corridor Management Area, Alaska. Snowden Mountain (shown) reaches an elevation of 1957 m.

Figure 9. One of the two previously unreported Dall sheep licks located in the Snowden Mountain ACEC, Utility Corridor Management Area, Alaska.

it appears that the component of the population varying the most between survey years was "ewe-like."

Because the ADFG did not conduct concurrent sheep surveys in contiguous areas, it is not known whether these changes in the sheep population resulted from emigration, sampling error, or other factors.

The boundary of the ADFG's large survey unit encompasses the Snowden Mountain ACEC. Unfortunately, sheep counted exclusively inside the ACEC were only recorded from 2004 to 2006. Nonetheless, the considerable variability in the number of sheep sighted in the ACEC during these 3 years—from 72 to 173 sheep—is perhaps reflective of changes in

Table 5. Sheep surveys in the upper Chandalar drainage (201,760 ha), June/July 2002–2006. Data taken from ADFG field reports, on file with the BLM.

Year	"Ewe-like"	Lambs	Lamb/ 100 ewes	Rams	Total
2002	884	221	25	434	1539
2003	621	114	18	254	989
2004	908	180	20	372	1460
2005	636	214	34	249	1099
2006	857	224	26	436	1517

the larger sample unit. From these associated observations we postulate that movement of sheep in and out of the ACEC is a common event prompted by unknown factors.

The greatest number of sheep found during the ADFG surveys was in 2005, when over 25% of the total sheep sighted (173) were lambs. This high proportion of lambs may illustrate the value of the ACEC's rugged escape terrain to lambing ewes.

Earth Cover Use

Sheep within the Snowden Mountain ACEC used the grouped Low Shrub category (Low Shrub, Dwarf Shrub, etc.) marginally more than available and the grouped Sparsely Vegetated and Rock/Gravel category much more than available ($\chi^2 = 13.66$, df = 2, $P = 0.001$). Of all the ACECs analyzed, Snowden Mountain showed the greatest use of the Rock/Gravel habitat class. Sheep used the All Other class moderately less than available.

West Fork Atigun ACEC

Summer Use

The West Fork Atigun ACEC (Figure 10) is located on the north side of the largest tributary of the Atigun River. We do not have complete earth cover data for this area. However, the data we do possess indicate that the ACEC is largely composed of the non-vegetated category Rock/Gravel. The more vegetated areas are dominated by Dwarf Shrub and Dwarf Shrub – Lichen communities.

We conducted habitat and population surveys in the West Fork Atigun ACEC in 2003, 2004, and 2006. In nearly every survey visit, we found fewer sheep than in the other ACECs.

We conducted one sheep habitat survey in late June 2003 and another in mid-July 2006. Although the 2003 survey occurred after sheep usually move to summer range (Summerfield 1974), deep snow throughout the upper elevations of the ACEC prevented sheep from occupying most of the ACEC. As a result, we located only 2 small bands of sheep (one of rams, one of ewes) in the ACEC during that visit. However, we also spotted 5 other herds of sheep just outside the ACEC boundary. These animals were on the west-facing slopes across the West Fork Atigun River, where snow depth was much lower. In contrast, during our July 2006 flight, when snow levels were very low, we found 17 sheep in the ACEC. Summerfield (1974) also found that snow depth greatly influences sheep movements in the Atigun River valley, with sheep generally following small tributaries upward as snow melts during the summer until they ultimately arrive at the level of the remaining glaciers.

During 2003 and 2006 habitat survey flights, we spotted ewes near 2 licks in adjacent ravines in the ACEC. Only one of these licks had been previously reported (BLM 1989); the other is a new, heretofore unreported lick (Figures 11 and 12). Both of these mineral licks were located in black shale substrate similar to that described in Jakimchuk et al. (1984).

Jakimchuk et al. (1984) identified a lambing area on the south-facing slopes of the mountains west of Atigun River and near the confluence of the Atigun and West Fork Atigun rivers. This lambing area is just outside the West Fork Atigun ACEC to the northeast.

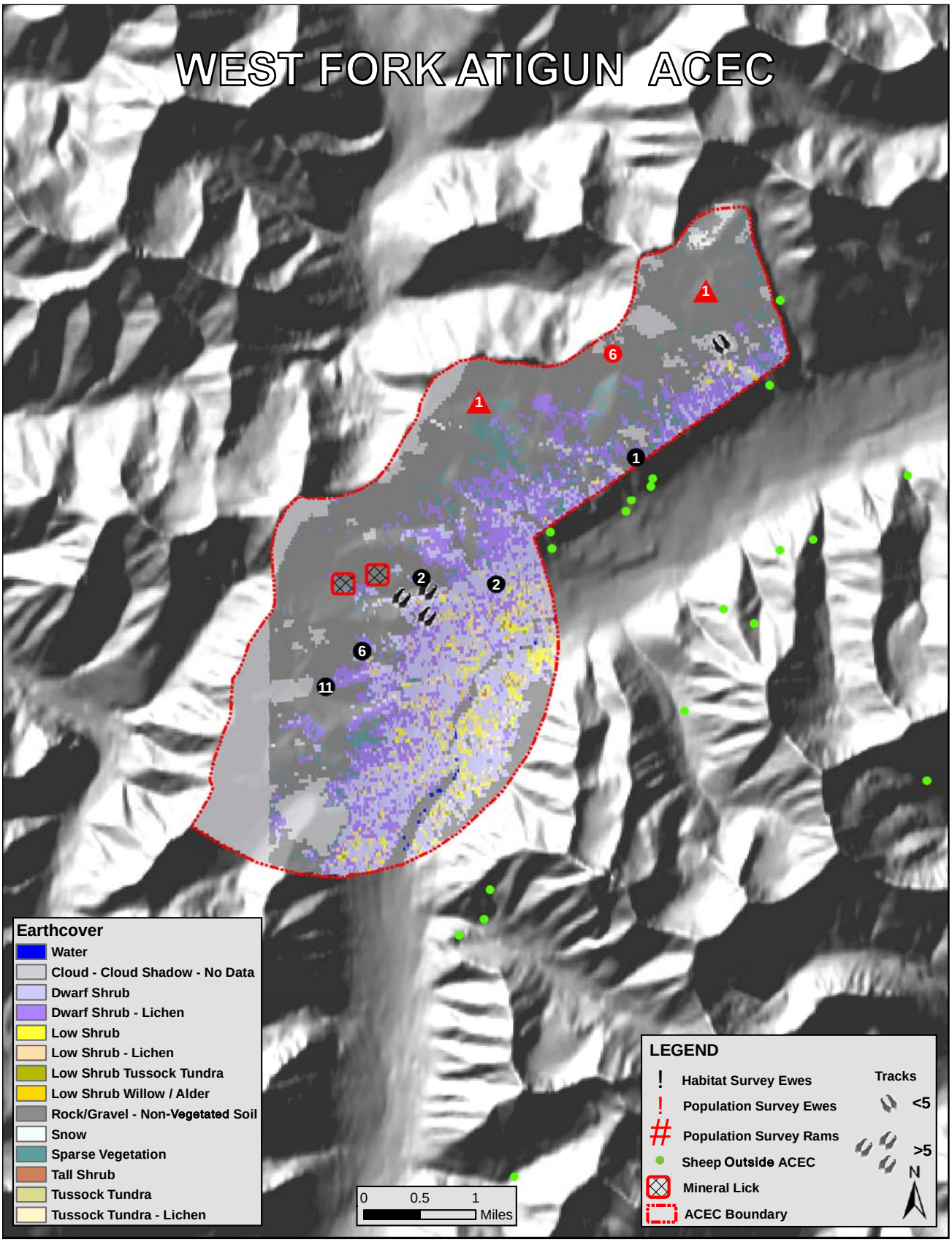

Figure 10. Dall sheep observations in West Fork Atigun ACEC, Utility Corridor Management Area, Alaska.

Figure 11. Previously unreported Dall sheep lick (indicated by arrow) in the West Fork Atigun ACEC, Utility Corridor Management Area, Alaska. Another lick reported by BLM (1989) is located in the next ravine to the right (southwest) and is shown in Figure 12 below.

Figure 12. Dall sheep lick reported by BLM (1989) in the West Fork Atigun ACEC, Utility Corridor Management Area, Alaska.

While we found no evidence of lambing within the ACEC proper, we did encounter ewes and lambs just outside the ACEC boundary to the southeast. The nearest escape terrain to these ewes and lambs was located within the West Fork Atigun ACEC, so we infer that these animals lambed within its boundaries.

Winter Use

We located the tracks of one group of sheep in the West Fork Atigun ACEC during a survey flight in September 2003 and spotted 2 rams at a different location. In April 2004, 7 months later, we found sheep tracks in another area and again spotted 2

rams in the ACEC. In January 2004, we made ground-based observations from the Dalton Highway near the ACEC's eastern boundary. During these sightings we again observed 2 rams in the ACEC, but also spotted 11 other sheep just east of the boundary and nearer the highway.

These observations reveal that the West Fork Atigun ACEC was consistently used throughout that winter. They also show that, unlike the sheep that winter in the Snowden Mountain ACEC on windswept ridges, the sheep in the West Fork Atigun ACEC winter at lower elevations on toe slopes. In spite of this apparent contrast, snow depth probably drove the wintering sheep's habitat selection in both ACECs; ridge tops and steep, south-facing toe slopes hold less snow than surrounding habitats. Summerfield (1974), who found that sheep in the Atigun River valley wintered on low-elevation, south-facing slopes, postulated that these sites attracted sheep due to higher temperatures and shallower snow, which increases foraging efficiency.

In summary, our observations indicate that deep snow forces sheep to select from 2 strategies to survive the harsh winters in the Brooks Range: reside on wind-swept ridges or move to lower elevations with a southern exposure. Sheep in the West Fork Atigun ACEC appear to select the second strategy. While only a few sheep winter in the ACEC proper, more use the area just outside the ACEC boundary at even lower elevations.

Population Surveys

The ADFG surveyed this ACEC once during the study period (2006) and found only 8 sheep. However, ADFG researchers counted many individuals (126) near the northeast and southwest boundaries of the ACEC.

Earth Cover Use

Due to the small number of observed locations in the West Fork Atigun ACEC, the chi-square analysis offered inconclusive results. However, we were able to draw broad conclusions from data collected. Of the 10 sheep locations documented in surveys, 7 were in the Rock/Gravel class. The remaining 3 were in the Sparse Vegetation, Dwarf Shrub – Lichen, and Cloud classes. We conclude from these data that sheep in the West Fork Atigun ACEC, like those in the other ACECs, mostly used areas with little vegetation at high elevation ($x = 1451$ m ± 227 m).

Galbraith Lake ACEC

Summer Use

The Galbraith Lake ACEC (Figures 13 and and 14), the largest of the 5 ACECs, contains Galbraith Lake and 3 large drainages that feed the lake. The ACEC encompasses the Atigun River valley and portions of the mountains on both sides of the valley. The major vegetation communities in the ACEC are Dwarf Shrub and Dwarf Shrub – Lichen.

We conducted aerial habitat surveys in this ACEC 3 times (2003, 2004, and 2006). We found only 2 herds of sheep (ewes and lambs) in the summer of 2003 and no sheep in the summer of 2006. Similarly, ADFG researchers spotted few sheep during their population survey in July 2006. In contrast, during the habitat flight in late May 2004 we spotted 129 sheep, 17 of which were lambs.

The differences in the number of sheep observed during these flights probably reflect a pattern in the sheep's seasonal movement rather than actual changes in the sheep population among years. Jakimchuk et al. (1984) observed that sheep use the west- and south-facing slopes on the east side of the Atigun River valley near Atigun Gorge during the spring as lambing-nursery areas, where they find an early flush of green plants in the spring (Summerfield 1974). In fact, BLM employees have counted up to 200 sheep in the area known as "Black Mountain" (Figure 15) in the spring when green vegetation is just beginning to emerge (Roger Delaney, BLM, pers. comm.). We made ground-based observations of sheep in the northern part of the ACEC from the Dalton Highway in June 2000 and 2003 and noted 27 and 54 sheep (small rams and ewes/lambs, respectively) in the area around Black Mountain.

Our observations confirm that the foothills east of Galbraith Lake are valuable to sheep in the early spring, both as a lambing area

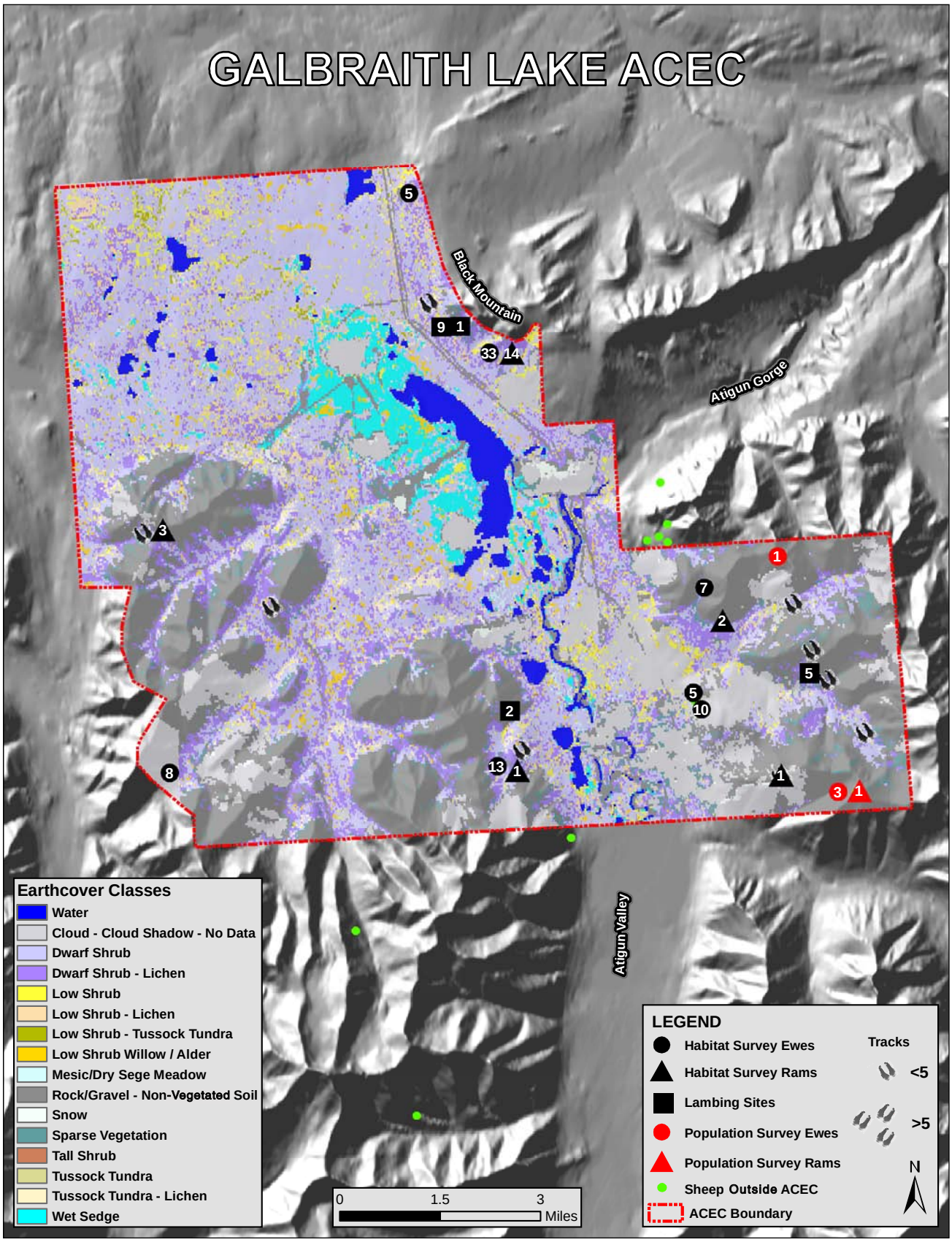

Figure 13. Dall sheep observations in Galbraith Lake ACEC, Utility Corridor Management Area, Alaska.

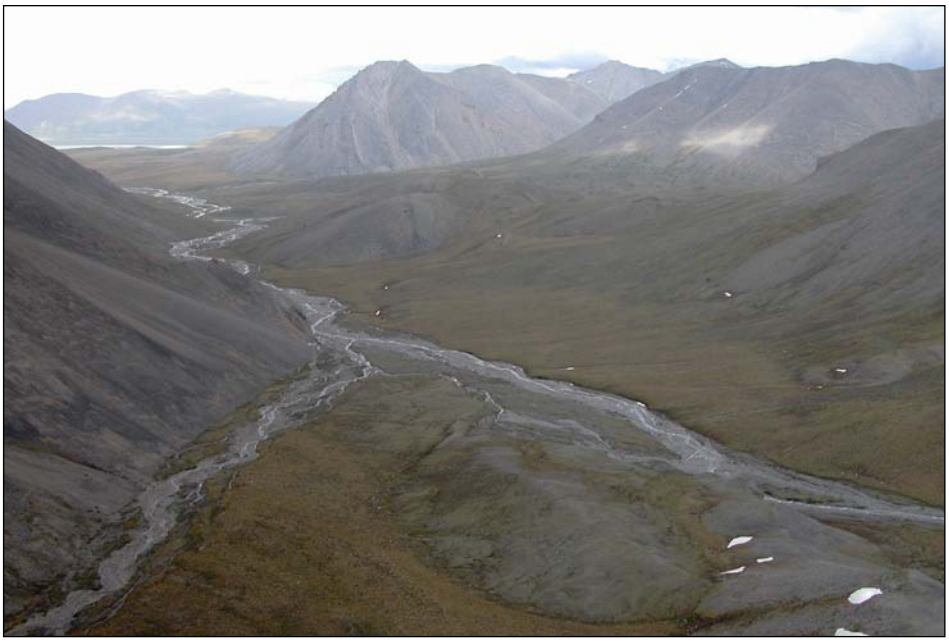

Figure 14. View to the northeast from the southwestern border of the Galbraith Lake ACEC, Utility Corridor Management Area, Alaska. Galbraith Lake is visible in the background.

and as a spring foraging area, particularly for nursing ewes. (Of the 17 total lambs spotted in the ACEC, 10 were in this area.) Summerfield (1974) noted that as the summer season progresses, sheep move to higher elevations in the Atigun River drainage. Similarly, our observations suggest that there is a seasonal movement of animals from lower-elevation spring foraging areas to higher elevations in, or even out of, the ACEC each summer.

Summerfield (1974) and Daum (1982) had previously identified a potential mineral lick in the ACEC. However, we did not observe sign of recent use of this, or any other mineral lick, in the Galbraith Lake ACEC during our surveys.

Winter use

We found sheep tracks in 6 locations in the ACEC during a flight in September 2003. Groups of fewer than 5 animals accounted for all of these tracks. We also observed 1 ram during this flight. In another winter flight in April 2004, we detected 23 individual sheep, as well as the tracks of other sheep, in 4 areas in the ACEC. Each observation of tracks was of fewer than 5 animals. These sightings occurred throughout the ACEC either on high ridges or low toe-slopes, probably in response to snow depth. In addition, we observed the ACEC from the ground along the Dalton Highway near Black Mountain in November 2005 and spotted sheep, both ewes and rams, using the lower slopes of the northwest portion of the ACEC.

Population surveys

ADFG surveyed this ACEC once during the study period (2006) and found only 6 sheep in the ACEC.

Earth cover use

Clouds obscured several important habitat areas in the satellite image that served as the basis for the earth cover classification of the Galbraith Lake ACEC. Unfortunately, several sheep locations were in this Cloud class, and analysis provided the least conclusive data ($\chi^2 = 3.13$, df = 2, $P = 0.209$) of all of the habitat use analyses we conducted. The data not in the Cloud class indicate that dwarf shrub classes have no relationship between availability and sheep use, as we found in the Poss Mountain ACEC. As with most of the other ACECs, sheep used the Rock/Gravel class marginally more than available but used the All Other class marginally less than available.

Figure 15. Up to 200 Dall sheep have been sighted in the vicinity of Black Mountain, located on the northeastern boundary of Galbraith Lake ACEC appoximately 2 km northeast of the lake.

General Observations and Summary

We determined that all of the ACECs were used by sheep year-round for summering, wintering, and lambing areas. Our surveys were conducted opportunistically due to funding, weather, and other logistical reasons. As a result they were both spatially and temporally uneven. Nonetheless, we found that the Nugget, Poss Mountain, and Snowden Mountain ACECs and the northeastern portion of the Galbraith Lake ACEC are of particular importance to sheep, probably because these areas contain a great deal of escape terrain juxtaposed with foraging habitat compared to areas outside the ACECs. Of these 4 ACECs, the Snowden Mountain ACEC consistently hosted the greatest number of animals during our survey visits. Snowden Mountain ACEC also contains proportionally more of these critical habitats than the other ACECs.

We found that sheep generally selected summer habitats that were in the Rock/Gravel and/or Sparse Vegetation classes. Similarly, we usually found lambing ewes in habitat that was in or near escape terrain, which also falls into these classes. This behavioral trait has been observed elsewhere by others (Rachlow and Bowyer 1998). It is important to note that the Rock/Gravel and Sparse Vegetation classes are not devoid of vegetation. By definition, vegetation makes up less than 20% of the cover in the Rock/Gravel earth cover class and between 20% and 50% in the Sparse Vegetation class. Sheep are known to inhabit open, rocky, relatively dry habitats at high elevations, where predation and competition for forage from other ungulates are reduced (Lawson and Johnson 1982). Vegetation is characteristically sparse in areas that meet those criteria in the ACECs we studied.

Due to public interest in sheep rams, we analyzed data on their occurrence in the ACECs to develop information on their habitat preferences. Throughout the entire study, we counted rams 144 times. These comprised 11.7% of the total sheep sighted during the study. Although each ACEC contains unique topography, we found that the elevations and habitat used by rams during summer months were somewhat uniform across all ACECs. Over 97% of all rams counted were found in 5 earth cover classes: Low Shrub, Low Shrub – Lichen, Dwarf Shrub, Dwarf Shrub – Lichen, and Rock/Gravel. The mean elevations used by rams in all study areas was 1194 m (±265 m), and the elevations at which rams were spotted did not vary by more than 175 m in any of the ACECs. (We omitted West Fork Atigun ACEC from this analysis because so few rams were observed there.) Because elevation and earth cover class were so diagnostic, we estimated how much habitat rams were using in each

Table 6. Areas used by Dall sheep rams in 4 ACECs in the Utility Corridor Management Area, Alaska.

Visit Site	Size of ACEC (ha)	Area Used (ha)	% of Total Used	Rams:Area Used (ha)
Poss Mountain	3237	975	30.1%	1:98
Nugget Creek	1335	151	11.3%	1:6
Snowden Mountain	11,331	6999	61.8%	1:97
Galbraith Lake	22,662	6858	30.3%	1:298

ACEC (Table 6). We found that although the Nugget Creek ACEC is by far the smallest ACEC in both area and percent area used, it appears to be very important to rams. In fact it accounted for only 3% of the total ACEC land area but contained 19% of the rams observed. In the Nugget Creek ACEC the ratio of ram to units of used habitat (ha) was 1:6, in contrast to ratios of 1:97 or higher for the other ACECs.

Sheep were not using some of the previously reported sheep licks in the ACECs during our study. However, they were using other licks that had not been previously reported. This finding probably does not negate the importance of the historic licks, but rather, shows that there is some variability in the use of licks by sheep over time.

Sheep appeared to have 2 strategies in selecting wintering areas. They selected either high, wind-swept ridges or lower, steep slopes that were oriented to the south and west. We hypothesize that snow depth is the driving factor in selecting both of these wintering areas.

We observed sheep a total of 1212 times within the boundaries of the 5 ACECs. In addition, we observed hundreds of sheep just outside the ACECs' boundaries. The largest numbers of these "extra-ACEC" sheep were around the Snowden Mountain and West Fork Atigun ACECs. These animals probably use the ACECs as well.

The productivity of sheep in our study areas, when all years and all ACECs were combined, was 30.4 lambs/100 ewes (R = 0 – 39; SD ±12.58). The productivity of sheep in the Atigun River valley has previously been reported to be 43 lambs/100 ewes (Jakimchuk et al. 1984), 36 lambs/100 ewes (Summerfield 1974), and 30.8 lambs/100 ewes (Nichols 1978). The productivity of the sheep population in a large survey unit on the south side of the Brooks Range averaged 24.6 lambs/ 100 ewes over 5 years from 2002 to 2006 (R = 18 – 36; SD ±6.23; ADFG survey results on file with the BLM).

Unfortunately, budget and environmental constraints precluded repeated surveys in each year and consistent survey effort on each survey. As a result, sources of sampling error cannot be discounted in our population data. However, it appears that the sheep populations in the ACECs fluctuate markedly. It also appears that the Snowden Mountain ACEC had a particularly large population shift in consecutive years, similar to the fluctuations detected by the ADFG in its surveys in the nearby Chandalar drainage survey unit, which encompasses the Snowden Mountain ACEC. The factors that affect production of sheep and drive the aforementioned fluctuations in the sheep population are not known. Further study is needed to determine the contribution of seasonal and annual movements, fecundity, and lamb mortality to the dynamics of the sheep populations within the ACECs and in the general area.

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Appendix A. Alaska Earth Cover Classification Class Descriptions

(BLM et al. 2003)

1.0 Forest

Needleleaf and Deciduous Trees

The needleleaf species generally found were white spruce (*Picea glauca*) and black spruce (*P. mariana*). White spruce tended to occur on warmer sites with better drainage, while black spruce dominated poorly drained sites and was more common in the interior of Alaska. The needleleaf classes included both white and black spruce.

The deciduous tree species generally found were paper birch (*Betula papyfera*), aspen (*Populus tremuloides*) and cottonwood (*P. balsamifera* and *P. trichocarpa*). Black cottonwoods (*P. trichocarpa*) were generally found only in river valleys and on alluvial flats. Under some conditions willow (*Salix* spp.) and alder *(Alnus rubra)* formed a significant part of the tree canopy. Deciduous stands were found in major river valleys, on alluvial flats, surrounding lakes, or most commonly, on the steep slopes of small hills. Mixed deciduous/coniferous stands were present in the same areas as pure deciduous stands. While needleleaf stands were extensive, deciduous and mixed deciduous/coniferous stands were generally limited in size. The only exception to this rule was near major rivers, where relatively extensive stands of pure deciduous trees occurred on floodplains and in ancient oxbows.

1.1 Closed Needleleaf

At least 60% of the cover was trees, and ≥75% of the trees were needleleaf trees. Closed needleleaf sites were rare because even where stem densities were high, the crown closure remained low. Generally, closed needleleaf sites were found only along major rivers.

1.2 Open Needleleaf

From 25% to 59% of the cover was trees, and ≥75% of the trees were needleleaf. This class was very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses, and lichens.

1.21 Open Needleleaf – Lichen

From 25% to 59% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen.

1.3 Woodland Needleleaf

From 10% to 24% of the cover was trees, and ≥75% of the trees were needleleaf. Woodland understory was extremely varied and included most of the shrub, herbaceous, or graminoid types present in the study area.

1.31 Woodland Needleleaf – Lichen

From 10% to 24% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen. The lichen often occurred in small, round patches between trees. Within the study area, this class was generally found along ridgetops or on riparian benches.

1.4 Closed Deciduous (Mixed Deciduous Species 1.45)

At least 60% of the cover was trees, and ≥75% of the trees were deciduous. Occurred in stands of limited size, generally on the floodplains of major rivers, but occasionally on hillsides, riparian gravel bars, or bordering small lakes. This class included paper birch, aspen, or cottonwood.

1.41 Closed Birch

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were paper birch.

1.42 Closed Aspen

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were aspen. Stands of pure aspen occurred, but were generally no larger

than a few acres. They were found on steep slopes, with particular soil conditions, and on river floodplains.

1.43 Closed Poplar

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were cottonwood.

1.44 Closed Deciduous – Willow Complex

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥60% of the deciduous trees were of the *Salix* genus, tree form.

1.5 Open Deciduous (Mixed Deciduous Species 1.55)

From 25% to 59% of the cover was trees, and ≥75% of the trees were deciduous. There was generally a needleleaf component to this class, though it was less than 25%. This was a relatively uncommon class.

1.51 Open Birch

From 25% to 59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were paper birch. This class was very rare. No examples of this class were found in the study area.

1.52 Open Aspen

From 25 to 59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were aspen.

1.53 Open Cottonwood

From 25% to 59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were cottonwood.

1.54 Open Deciduous – Willow Complex

At least 25%–59% of the cover was trees, ≥75% of the trees were deciduous, and ≥60% of the deciduous trees were of the *Salix* genus, tree form.

1.6 Closed Mixed Needleleaf/Deciduous

At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class was uncommon and found mainly along the meanders of major rivers.

1.7 Open Mixed Needleleaf/Deciduous

From 25% to 59% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class occurred in regenerating burns, on hill slopes, or on the borders of lakes.

2.0 Shrub

The tall and low shrub classes were dominated by willow species, dwarf birch (*B. nana* and *B. glandulosa*) and *Vaccinium* species, with alder being somewhat less common. However, the proportions of willow to birch and the relative heights of the shrub species varied widely, which created difficulties in determining whether a site was made up of tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictated whether the site was called a low or tall shrub. The shrub heights were averaged within a genus, as in the case of a site with both tall and low willow shrubs. Dwarf shrub was usually composed of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. The species composition of this class varied widely from site to site and included rare plant species. It is nearly always found on hilltops or mountain plateaus and may have included some rock.

2.1 Tall Shrub

Shrubs made up 25%–100% of the cover and shrub height was ≥1.3 m. This class generally had a major willow component that was mixed with dwarf birch and/or alder, but could also have been dominated by nearly pure stands of alder. It was found most often in wet drainages, at the head of streams, or on slopes.

2.21 Low Shrub – Willow/Alder

Shrubs made up 25%–100% of the cover, shrub height was .25–1.3 m, and ≥75% of the shrub cover was willow and/or alder.

2.22 Other Low Shrub/Tussock Tundra

Shrubs made up 25%–100% of the cover, shrub height was .25–1.3 m, and ≥35% of the cover was made up of tussock-forming cottongrass *(Eriophorum vaginatum*). This class

was found in extensive patches in flat, poorly drained areas. It was generally made up of cottongrass, ericaceous shrubs, willow and/or alder shrubs, other graminoids, and an occasional black spruce.

2.23 Low Shrub – Lichen Other

Shrubs made up 25%–100% of the cover, shrub height was .25–1.3 m, and ≥20% of the cover was made up of lichen. This class was found at mid- to high elevations. The shrub species in this class were nearly always dwarf birch.

2.24 Low Shrub – Other

Shrubs made up 25%–100% of the cover, and shrub height was .25-1.3 m. This was the most common low shrub class. It was generally composed of dwarf birch, willow species, *Vaccinium* species, and *Ledum* species.

2.31 Dwarf Shrub – Lichen

Shrubs made up 25%–100% of the cover, shrub height was ≤.25 m, and ≥20% of the cover was made up of lichen. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. It was nearly always found at higher elevations on hilltops, mountain slopes and plateaus. This class may be more open than the Dwarf Shrub – Other class.

2.31 Dwarf Shrub – Other

Shrubs made up 25%–100% of the cover, and the shrub height was ≤.25 m. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species but often included a variety of forbs and graminoids, and some rock. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

3.0 Herbaceous

The classes in this category included bryoids, forbs, and graminoids. Bryoids and forbs were present as a component of most of the other classes but rarely appeared in pure stands. Graminoids such as *Carex* spp., *Eriophorum* spp., or bluejoint grass (*Calamagrostis canadensis*) may have dominated a community.

3.11 Lichen

Composed of ≥40% herbaceous species, ≤25% water, and ≥ 60% lichen species.

3.12 Moss

Composed of ≥40% herbaceous species, ≤25% water, and ≥60% moss species.

3.21 Wet Graminoid

Composed of ≥40% herbaceous species, ≤25% water, and where ≥60% of the herbaceous cover was graminoid and ≥20% of the graminoid cover was made up of *Carex aquatilis*. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

3.31 Tussock Tundra

Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid and ≥35% of the graminoid cover was made up of tussock-forming cottongrass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs, bryoids, and other graminoids. This class was usually found at lower elevations in flat, poorly drained areas.

3.311 Tussock Tundra/Lichen

Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, ≥20% of the cover was lichen, and ≥35% of the graminoid cover was made up of tussock-forming cottongrass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs and other graminoids. This class, usually found at lower elevations in flat, poorly drained areas, included a major component of lichen.

3.34 Mesic/Dry Graminoid

Composed of ≥40% herbaceous species, ≤5% water, with ≥50% graminoids excluding tussock-forming cottongrass and *Carex aquatilis*. This class was not common and was found generally only at high elevations.

3.35 Mesic/Dry Forb

Composed of ≥40% herbaceous species, ≤5% water, with <50% graminoids. Regenerating burn areas dominated by fireweed *(Epilobium angustifolium)* fell into the mesic/dry forb

category. However, forb communities without significant graminoid or shrub components were generally rare in the interior of Alaska.

4.0 Aquatic Vegetation

The aquatic vegetation was divided into Aquatic Bed and Emergent classes. The Aquatic Bed class was dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The Emergent Vegetation class was composed of species that were partially submerged in the water, and included freshwater herbs such as horsetails (*Equisetum* spp.), marestail (*Hippuris* spp.), and buckbean (*Menyanthes trifoliata*).

4.1 Aquatic Bed

Aquatic vegetation made up ≥20% of the cover, and ≥20% of the vegetation was composed of plants with floating leaves. This class was generally dominated by pond lilies.

4.2 Emergent Vegetation

Aquatic vegetation made up ≥20% of the cover, and ≥20% of the vegetation was composed of plants other than pond lilies. Generally included freshwater herbs such as horsetails, marestail, or buckbean.

5.0 Water

5.1 Clear Water

Composed of ≥80% clear water.

5.2 Turbid Water

Composed of ≥80% turbid water.

6.0 Barren

This class included sparsely vegetated sites, e.g., abandoned gravel pits or riparian gravel bars, along with non-vegetated sites, e.g., barren mountaintops or glacial till.

6.1 Sparse Vegetation

At least 50% of the area was barren, but vegetation made up >20% of the cover. This class was often found on riparian gravel bars, on rocky or very steep slopes, and in abandoned gravel pits. The plant species were generally herbs, graminoids, and bryoids.

6.2 Rock/Gravel

At least 50% of the area was barren, ≥50% of the cover was composed of rock and/or gravel, and vegetation made up less than 20% of the cover. This class was most often made up of mountaintops or glaciers.

6.3 Non-vegetated Soil

At least 50% of the area was barren, ≥50% of the cover was composed of mud, silt or sand, and vegetation made up less than 20% of the cover. This type was generally along shorelines or rivers.

7.0 Urban

At least 50% of the area was urban. This class was only found in the study area within the village of Ruby.

8.0 Agriculture

At least 50% of the area was agriculture. This class was not found in the study area.

9.0 Cloud/Shadow

At least 50% of the cover was cloud or shadow.

9.1 Cloud

At least 50% of the cover was made up of clouds.

9.2 Cloud Shadow

At least 50% of the cover was made up of cloud shadows.

9.3 Terrain Shadow

At least 50% of the cover was made up of terrain shadows.

10.0 Other

Sites that did not fall into any other category were assigned to Other. For example, sites containing 25%–80% water, <25% shrub, and <20% aquatic vegetation were classed as Other. Sites classed as Other may have also included extensive areas of vegetative litter, such as downed wood.