Demography and Home Ranges of Dall's Sheep in the Central Brooks Range, Anaktuvuk Pass, Alaska

Gates of the Arctic National Park and Preserve

Final Report: 2004

Jim Lawler

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Table of Contents

Table of Contents ……………………………………………..……………….1

List of Figures…………………………………………………….………………….2

List of Tables…………………………………………………………………...3

Appendix…………………………………………………………………...…...4

Executive Summary …………………………………………………………5

Introduction ....………...……8

Goals and Objectives……….……………………..………………………...…….9

Study Area ....………..……………...9

I. Morphometric Measures, Age Structure and Survival of Captured Sheep
Methods...................………...………..10
Results and Discussion...................………............................…………11

II. Sheep Movements
Methods...................………...………..17
Results and Discussion...................………............................…………18

III. Sheep Trend Count Surveys in GAAR 1998-2002
Aerial Surveys
Methods……………………………………………………………32
Results and Discussion………………………………………….34
Ground Surveys
Methods……………………………………………………………43
Results and Discussion………………………………………….43

IV. Dall's sheep Harvest by Subsistence Users, Anaktuvuk Pass, Alaska
Methods...................………...………..46
Results and Discussion...................………............................………..…46

V. Management Implications…………...…………………………………….47

Acknowledgements………………………………………………………...48

Literature Cited…………………………………………………………….49

List of Figures

Fig. 1. Locations of Dall's sheep captured and radiocollared Dall's sheep mortalities near Anaktuvuk Pass, Alaska ……………………………………………………………12

Fig. 2. Age distribution of Dall's sheep captured for radiocollaring near Anaktuvuk Pass, Alaska in March of 1998, 1999, 2000 and 2001………………………………………15

Fig 3. The Kaplan-Meier survival function with 95% confidence intervals for Dall's sheep near Anaktuvuk Pass, Alaska from March 1998-March 2002…………….……...16

Fig. 4. Group size, elevation, distance to escape terrain and the percentage of time the animal was observed in a mixed sex group for Dall's sheep in Gates of the Arctic National Park and Preserve, Alaska………………………………………...………21

Fig. 5. The relationship of the number of relocations (sample size) for individual sheep and the size of the estimated home range (km^2) ……………………………………..…23

Fig. 6. Dall's sheep home ranges near Anaktuvuk Pass, Alaska from March 1998 to March 2002 determined using Minimum Convex Polygons……………………….………24

Fig. 7. Dall's sheep utilization distribution (95% kernel) near Anaktuvuk Pass, Alaska from March 1998 to March 2002…………………………………………………...……25

Fig. 8. Dall's sheep core use distribution (50% kernel) near Anaktuvuk Pass, Alaska from March 1998 to March 2002…………………………………………………...……26

Fig. 9. Dall's sheep winter (January, February, March and April) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002…………………………...…27

Fig. 10. Dall's sheep lambing (May and June) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002…………………………………………..……….28

Fig. 11. Summer Dall's sheep (July and August) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002……………………………………...………29

Fig. 12. Fall Dall's sheep (September and October) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002……………………………………………...30

Fig. 13. Dall's sheep rutting (November and December) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002……………………………………..…31

Fig. 14. Survey units used for aerial counts of Dall's sheep during June and July 1998-2002 near Anaktuvuk Pass, Alaska…………………………………………………...…33

Fig. 15. The relationship between the numbers of sheep observed and the time spent surveying in four survey units to the east and four survey units to the west of Anaktuvuk Pass, Gates of the Arctic National Park and Preserve, Alaska……………….……...…37

Fig. 16. Population densities of rams, ewe-like sheep and lambs east and west of Anaktuvuk Pass, Alaska from aerial surveys July 1998-2002……………………..……40

Fig. 17. Locations of ground surveys used to count, sex and age Dall's sheep during July 1999 and 2000 near Anaktuvuk Pass, Alaska……………………………………………45

List of Tables

Table 1. Physical characteristics and survival status of Dall's sheep captured for radiocollaring in Gates of the Arctic National Park and Preserve, Alaska. Sheep were captured in March 1998, March 1999 and March 2000…………………………………14

Table 2. Seasonal distribution of Dall's sheep radiocollared in Gates of the Arctic National Park and Preserve, Alaska March 1998-March 2002…..……………………....19

Table 3. Summary statistics for individual Dall's sheep gathered during radiotracking flights in Gates of the Arctic National Park and Preserve, 1998 –2002……………..….20

Table 4. Lamb:ewe-like and ram:ewe-like ratios in a survey area to the west of Anaktuvuk Pass and to the east of Anaktuvuk Pass, Alaska…………….………….....35

Table 5. Summary statistics for survey effort of summer aerial Dall's sheep surveys near Anaktuvuk Pass, Alaska …………………..…………………………………………36

Table 6. Observed sheep densities, survey rates and search rates from 1974, 1982, 1984, 1987 and 1996 and mean (± 90% Confidence Interval) sheep densities, survey rates and search rates from 1998-2002 for a survey area west of Anaktuvuk Pass and a survey area east of Anaktuvuk Pass, Alaska..…………………………………………..…...…40

Table 7. Proportion of observed sheep composed of lambs and rams > quarter curl from 1982, 1984, 1987, 1996 and 1998-2002 for survey areas west and east of Anaktuvuk Pass, Alaska…………………………………………………………………..….41

Table 8. Dall's sheep harvest for the community of Anaktuvuk Pass, Alaska. Records have been maintained since the initiation of a community harvest quota of 60 Dall's sheep……………………………………………………………………………47

Appendices

Appendix 1. Summary of June / July Dall's sheep surveys near Anaktuvuk Pass, Alaska 1996-2002. Sheep surveys in 1996 were flown with helicopters and surveys done in 1998-2002 were done with fixed-wing aircraft…………………………….……….51

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Executive Summary

Sheep surveys and a four-year investigation of Dall's sheep home ranges were initiated to monitor and assess Dall's sheep population dynamics in the central Brooks Range near Anaktuvuk Pass, Alaska in March of 1998. This project was established with the following objectives: identify Dall's sheep sub-populations and determine band sizes; determine home ranges, seasonal distribution, and range fidelity of the identified sub-populations; assess harvest potential of the bands; develop an economical and accurate annual trend survey technique, and; continue the exchange of information regarding Dall's sheep populations in the central Brooks Range with Anaktuvuk Pass residents.

Eighteen Dall's sheep (15 females and 3 males) were captured with a net-gun and radiocollared in March of 1998 to the east and west of Anaktuvuk Pass. In the subsequent two years, additional Dall's sheep were captured to replace those that had died or had radiocollar failure during the previous year (6 females and 2 males). The average weight (mean $\pm$ SE) of adult female sheep in Gates of the Arctic National Park and Preserve was 50 $\pm$ 2.1 kg (114 $\pm$ 5 lbs.). Average body weight was not calculated for male sheep due to a variety of factors including small sample size. Age at capture for radiocollared sheep in Gates of the Arctic National Park and Preserve averaged 8.4 years for males and 7.2 years for females. During the four years of this study, 14 of the radiocollared sheep died. The cause of death for 5 sheep is unknown, 1 sheep died from stress after being trapped in snow three weeks after capture, 1 sheep was harvested by a human, and 3 sheep died from predation.

During this study (March 1998 – March 2002), 69 radiotracking flights occurred and sheep were located in every month of the year. Data from all flights are included in this report. The length of time between radiotracking flights was dictated by scheduling (minimum of five days between flights to avoid autocorrelation) and weather. As a result, time between sheep relocations varied greatly (range = 6 – 69 days) making

movement speeds based on sequential sheep locations and calculations of daily movement rates inconsequential. Sheep home ranges determined using minimum convex polygons (MCP) ranged from 47.5 km^2 to 128.1 km^2 (18.3 mi^2 to 49.5 mi^2). Mean home range size was 72.4 $\pm$ 5.04 km^2 (28.0 $\pm$ 1.95 mi^2). In some instances home range boundaries fell along obvious geographical barriers, in other instances, no obvious barrier existed. Analysis indicates two subpopulations within the radiocollared sample.

Aerial surveys were conducted near Anaktuvuk Pass, Alaska during June and July of 1998 – 2002. Weather conditions varied from sunny and clear, to windy and snowy. A total of 1230 km^2 (475 mi^2) were surveyed in 1998 and a total of 386 sheep were observed. Age and sex composition of Dall's sheep observed during the 1998 survey were 26 lambs:100 ewe-like sheep and 27 rams (> quarter curl):100 ewe-like sheep. In 1999, 1093 km^2 (422 mi^2) were surveyed and 186 sheep were observed. Age and sex composition of Dall's sheep observed during 1999 was 34 lambs:100 ewe-like sheep and 24 rams:100 ewe-like sheep. In 2000, 837 km^2 (323 mi^2) were surveyed and 460 sheep were observed. Age and sex composition of Dall's sheep observed during 2000 was 33 lambs:100 ewe-like sheep and 32 rams:100 ewe-like sheep. In 2001, 798 km^2 (308 mi^2) were surveyed and 285 sheep were observed. Age and sex composition of Dall's sheep observed during 2001 was 17 lambs:100 ewe-like sheep and 30 rams:100 ewe-like sheep. In 2002, 1230 km^2 (475 mi^2) were surveyed and 392 sheep were observed. Age and sex composition of Dall's sheep observed during 2002 was 29 lambs:100 ewe-like sheep and 22 rams:100 ewe-like sheep. With one exception, no increasing or decreasing trend is identifiable for Dall's sheep populations in the survey area. The one exception was an increase identified in the number of lambs in the survey area west of Anaktuvuk Pass (P=0.031). Evidence from aerial surveys suggests that sheep populations were considerably lower during this study (1998-2002) than they were in the mid-1980's.

Ground-based sheep composition counts, conducted concurrently with the fixed-wing surveys, were attempted in 1998 near a known mineral lick. During 1999, the ground-based sheep observation was modified into three hiking transects surveyed immediately following the 1999 aerial survey. In both situations, field efforts were ineffectual due to a combination of low sheep densities in surveyed areas and poor weather conditions. A new area was sampled along the John River in 2000 and sheep and weather conditions cooperated to provide some encouraging results. A total of 74 sheep were observed. For comparison to aerial survey work, 38 lambs:100 ewe-like sheep and 17 rams:100 ewe-like sheep were noted. A ground survey was attempted in 2001 but was not accomplished for a variety of reasons (the most problematic was snow fall that occurred just prior to the start of the survey). No ground surveys were attempted in 2002. An advantage of the ground-based survey is the greater degree of accuracy with which sheep can be classified into sex and age classes but this advantage is offset by the limited area and small sample sizes provided by ground based surveys.

The regulations for a community harvest quota of 60 sheep for the community of Anaktuvuk Pass went into effect in July 1997. In the 1997 season (July – December), 7 hunters reported taking 11 sheep (10 rams and 1 ewe). During the 1998 hunting season, 9 hunters reported taking 16 sheep (10 rams and 6 ewes). In the 1999 season, 10 hunters reported taking 17 sheep (13 rams and 4 ewes). During the 2000 season, 8 hunters have reported taking 12 sheep (4 rams, 7 ewes, and 1 lamb). In 2001, 5 sheep were taken by subsistence hunters (3 rams and 2 ewes). In 2002, the final year of this study, 8 sheep were harvested (6 rams and 2 ewes). Reported sheep harvest during the five years of this study was substantially lower than those reported in the early 1990's. It is uncertain if this change in reported harvest reflects a real reduction in harvest or if the quality of the data collected has changed.

Introduction

The National Park Service (NPS) is mandated by the Alaska National Interest Lands Conservation Act (ANILCA) (Section 201(4)(a)) "to protect...populations of...Dall sheep" (Section 201(4)(a)), "to provide the opportunity for continued subsistence uses" (Section 801(4), and "[to conserve] natural and healthy populations" (Section 815(1)). Dall's sheep (*Ovis dalli*) can be legally hunted throughout Gates of the Arctic National Park and Preserve by qualified subsistence users; sport hunting for sheep is permitted in the Preserve.

Dall's sheep are an important natural resource for Gates of the Arctic National Park and Preserve. For park visitors, they are the most reliably viewed large mammal within the park because they do not migrate, unlike caribou, and they are far more numerous than are moose, wolves, bears, or muskoxen. Singer (1984) estimated the Dall's sheep population of Gates of the Arctic National Park and Preserve to be 12,343 animals. Adams (1988), repeating a portion of Singer's survey, found 27% more sheep than Singer in the same area. Given a rough estimate of 100,000 Dall's sheep world-wide (Valdez and Krausman 1999), Gates of the Arctic National Park and Preserve harbors a large percentage of the world's population of Dall's sheep.

Anecdotal observations indicate that a widespread decline in populations of Dall's sheep occurred in Gates of the Arctic National Park and Preserve and throughout the Brooks Range, Alaska during the late 1980's through the mid-1990's. (Brubaker and Whitten 1998, F. Mauer, US Fish and Wildlife Service, pers. comm., J. Dau, Alaska Department of Fish and Game, pers. comm.). The widespread decline was attributed to a series of hard winters with deep snow which made forage hard to reach and made sheep vulnerable to predation.

During the mid-1990's, local shortages of caribou migrating through the Anaktuvuk Pass region created a desire by local residents to increase the Dall's sheep harvest in order to meet subsistence needs. This shift in focus among harvest species resulted in an emergency subsistence sheep hunt opening in Gates of the Arctic National Park and Preserve for local residents in July 1995. The increased emphasis on sheep as a subsistence species and anecdotes of a perceived sheep population decline led the park to cooperatively conduct a statistically valid Dall's sheep population survey with the Alaska Department of Fish and Game (ADF&G) in 1996. In 1997, we began working with Anaktuvuk Pass residents to develop a community harvest reporting system, and in 1998 we initiated a project looking at Dall's sheep home ranges and population surveys. This report presents our findings.

Prior to the initiation of data collection and deployment of radiocollars on Dall's sheep, residents of the community of Anaktuvuk Pass village were visited by Patty Rost (NPS) and Rachel Brubaker (NPS). Proposed aspects of this sheep project were discussed and concerns of this project were solicited. Two major issues were identified during these discussions. The first concern was the affect of radiocollars on Dall's sheep. The second concern was the use of drugs in wildlife that potentially could be harvested and consumed by humans. Partially as a result of these discussions, the NPS agreed to reduce the number of radiocollared sheep from a desired 30 individuals to 18. In addition, the NPS committed to capture methods for Dall's sheep that did not entail the use of drugs. Non-objection or support for the project vastly outweighed objections among Anaktuvuk Pass residents (Patty Rost, personal communication). A letter was obtained from the Nunamiut Corp. providing permission to land a helicopter on corporation lands if necessary during the collaring operation (1997, 1998, 1999). Collection permits for animal capture were obtained from the Alaska Department of Fish and Game (Permit numbers 97-03, 98-041, 99-059, 00-029).

Goals and Objectives

The goal of this Dall's sheep project and sheep trend surveys was to ensure healthy populations of Dall's sheep in the central Brooks Range near the community of Anaktuvuk Pass. To obtain this goal, the following objectives were identified:

- identify Dall's sheep sub-populations and determine band sizes;
- determine home ranges, seasonal distribution, and range fidelity of the identified sub-populations;
- develop an economical and accurate annual trend survey technique; and
- continue the exchange of information regarding Dall's sheep populations in the central Brooks Range with Anaktuvuk Pass residents.

Study Area

The study area is located in the northern part of Gates of the Arctic National Park and Preserve, east and west of the village of Anaktuvuk Pass (68° 08'N, 151° 45'W) and is roughly bisected by the continental divide.

The climate zone at this latitude is arctic; precipitation (total water in snow and rain) is low and ranges from 5-9 inches (13-25 cm). Snowfall ranges from 35-50 inches (89-127 cm). Yearly temperatures fluctuate from an average July maximum of 65°F (18°C) to an average February minimum of -10°F (-23°C) (National Park Service 1986). The predominant vegetation communities in the study area are *Dryas*-sedge-lichen tundra and *Dryas*-mixed herb-lichen tundra on well-drained ridges and mountain sides. Moist to wet tussock tundra predominates in the valleys; *Eriophorum vaginatum* is the primary tussock-former (Viereck et al. 1992).

I. Morphometric Measures, Age Structure and Survival of Captured Sheep

Methods

Sheep were captured with a net-gun fired from the shoulder using a helicopter (Robinson R-44) as a platform. In 1998, the helicopter was piloted by Jonathan Laravee and in 1999 and 2000 the ship was piloted by Rick Swisher. Barry Minor was the net-gunner during all capture seasons. Both helicopter pilots and the net-gunner were associated with Quick Silver Air, Fairbanks, AK. In 1998, 19 adult Dall's sheep were captured from March 24-26 and 18 of these were equipped with radiocollars with a four-hour delay mortality mode (ATS, Minneapolis, Minnesota). On 27 March 1999, 3 sheep were captured and fitted with radiocollars to replace animals that had died in the previous year and to maintain the study population at 18 animals. On March 8, 2000 an additional 5 sheep were captured and radiocollared to replace 3 animals that had died during the previous year and to replace 2 collars that had ceased to function.

A fixed wing aircraft (PA-18 Piper Supercub) was used during the capture operations to provide safety support and as a spotter plane with the intention of locating sheep bands and thereby improving the overall efficiency of the capture operation. Weather limited this aircrafts usefulness however, and in all years, the helicopter located the majority of sheep bands as well as conducted the capture. The helicopter was used to herd animals to terrain suitable for a capture attempt. Capture efforts were discontinued if the pursuit of an individual exceeded approximately three minutes, if the animal appeared unduly stressed, if the animal moved to where there was no suitable terrain for capture, or more often, if the animal refused to move out of inappropriate capture terrain. Many of the captures required no herding and were completed quickly.

Immediately following the netting of a sheep, the netgunner left the helicopter, restrained the sheep and positioned it so the airway was clear with the head elevated to prevent inhalation of material from the digestive tract. The sheep were blindfolded, restrained with leg hobbles, and removed from the net. Meanwhile, the helicopter pilot recorded the capture location on a GPS unit and shuttled biologists to the capture site. A blood sample was taken from the jugular or cephalic vein. The sheep was aged by counting horn annuli (Geist 1971) and by assessing incisor wear, weighed, and a series of physical measurements were taken. Morphometric measurements included horn length, horn base diameter, body length, chest girth, neck circumference, jaw length, and metatarsus length. A VHF radiocollar was then placed on the sheep, and the animal was released. No drugs were used in capture and handling.

Blood samples were taken from 19 animals in 1998, 2 animals in 1999, and 5 animals in 2000. Each evening, blood samples were centrifuged and frozen. Serum from these blood samples was sent to the Wyoming State Veterinarian Laboratory. A subsample of blood was sent to the Alaska Department of Fish and Game, Fairbanks, AK for long-term storage and additional subsamples are in storage at the NPS office, Fairbanks, AK.

Blood samples were screened for evidence of exposure to: infectious bovine rhinotracheitis virus, bovine viral diarrhea virus, parainfluenza 3 virus, respiratory syncytial virus, epizootic hemorrhagic disease virus, bluetongue virus and 5 serovars of Leptospira interrogans. In addition to blood samples, fecal pellets and throat swabs were obtained for sheep radiocollared during March 2000 to screen for internal parasites and pathogenic strains of *Pasteurella* spp., respectively.

Dall's sheep mortalities (Fig. 1) were initially investigated from the fixed-wing aircraft. At the earliest opportunity, sites were visited by snow machine or helicopter. Information regarding probable cause of death and age and condition of sheep at the time of death was collected. Sheep survival was investigated using the Kaplan-Meier procedure extended to allow staggered entry of new 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). Age distribution of sheep mortalities was investigated graphically.

Results and Discussion

Capture

Initial capture distribution in 1998 for radiocollared sheep was 9 ewes and 3 rams in the upper John River tributaries of Kollutuk and Till creek, 1 ewe in Kollutarak Creek and 5 ewes in Contact Creek. In 1999, 3 ewes were captured in the upper Akmagolik Creek area. In 2000, 3 sheep were captured in upper Confusion Creek (1 ram and 2 ewes) and 2 sheep were captured in upper Contact Creek (1 ram and 1 ewe) (Fig. 1). All sheep captured and radiocollared were adults. All animals were active and appeared healthy when released. In 1998, one animal died within three weeks of being captured. In 1999 and 2000, all newly captured sheep survived for a minimum of five months after being captured.

The average weight (mean $\pm$ SE) of female sheep in Gates of the Arctic National Park and Preserve was 50 $\pm$ 2.1 kg (114 $\pm$ 5 lbs.)(Table 1). For comparison, weights for two populations of radiocollared Dall's sheep ewes in interior Alaska near the town of Circle during March 1999 and March 2000 averaged 55 $\pm$ 1.2 kg (121 $\pm$ 2.7 lbs.; n=40) (Burch and Lawler 2001). Weights of ewes captured in the western Brooks Range of Alaska in March 2000 and 2001 averaged 53 $\pm$ 1.2 kg (117 $\pm$ 2.7 lbs.; n=37)(Kleckner et al. 2002). Weights were not obtained for male sheep in Gates of the Arctic National Park and

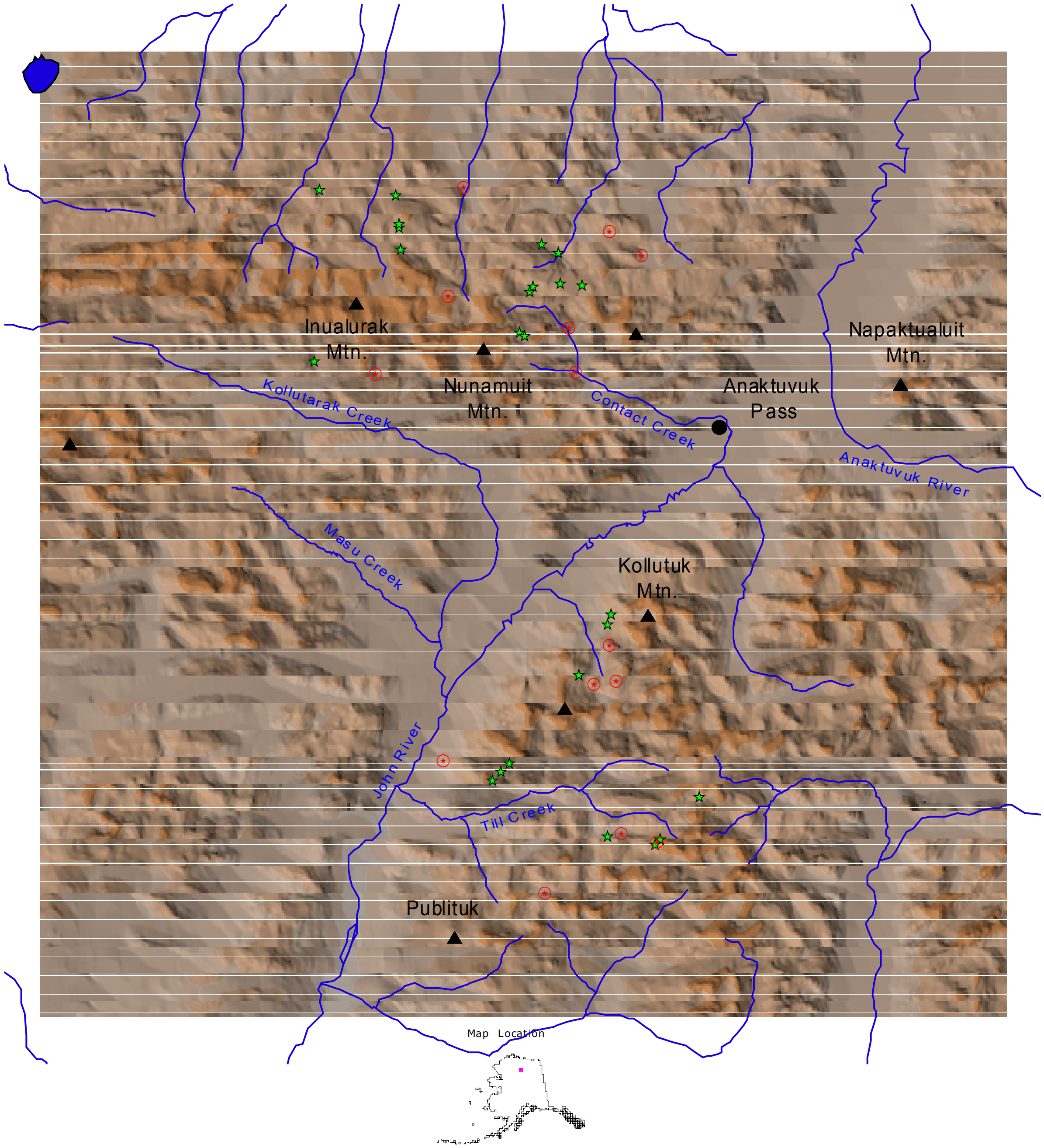

Fig. 1. Locations of Dall's sheep captured and radiocollared Dall's sheep mortalities near Anaktuvuk Pass, Alaska.

Preserve due to a combination of greater weights and considerably more vigorous struggles in comparison to females. This combination made obtaining accurate measures of ram weights difficult.

Age at capture for radiocollared sheep in Gates of the Arctic National Park and Preserve averaged 8.4 years for males and 7.2 years for females (Table 1). In the western Brooks Range, age estimated by counting horn annuli has a tendency to under estimate sheep ages in comparison to canine tooth cementum analysis in sheep older than eight because horn growth slowed appreciably after this age (Kleckner et al. 2002). Given these observations, mean sheep ages derived during this study may be under estimated.

Inferences regarding the age of the population of Dall's sheep in the study area can be made only from the first year of this study when 18 sheep were captured. In subsequent years, few sheep were captured (n=3 and n=5 in 1999 and 2000, respectively) limiting the usefulness of these samples. Based on the ages of the sheep captured during the 1st year of the study, ages of captured sheep were skewed toward older animals (Fig 2). Two explanations are plausible for the low numbers of young sheep captured. The first possibility is selectivity of captured animals by the capture crew. Because only adult sheep were targeted for capture, small bodied yearlings and small bodied sheep in general may have been avoided during the capture operation in favor of larger bodied mature ewes. This explanation however, is only plausible if ewes in the population are not reaching full body size until they are 6 years (i.e., there were few 2, 3, 4, and 5 year olds in the sample). Alternatively, the few individuals in these cohorts within the population may be the result of poor lamb production during the Brooks Range wide decline in sheep populations during the mid-90s. This bottle-neck in the age structure of this population may be due to a series of hard winters with deep snow (Brubaker and Whitten 1998, F. Mauer, US Fish and Wildlife Service, personal communication, J. Dau, Alaska Department of Fish and Game, pers. comm.) because lamb production has been shown to be related to winter snow depth during the winter prior to lambing (Murphy 1974, Nichols 1978).

Disease and Parasites

Blood samples were taken from 27 sheep captured for this study (n =27). All results were negative for exposure to infectious bovine rhinotracheitis virus, bovine viral diarrhea virus, parainfluenza 3 virus, respiratory syncytial virus, epizootic hemorrhagic disease virus, bluetongue virus and 5 serovars of Leptospira interrogans. Results from throat swabs did not reveal any pathologic strains of *Pasteurella* spp. Lung worm larvae were found and are typical of those found in other wild sheep populations. Eggs of larvae of several gastro-intestinal parasites were found and these also were typical of free ranging sheep. These results do not indicate a potential health problem to the sheep population or to humans consuming sheep.

Table 1. Physical characteristics and survival status of Dall's sheep captured for radiocollaring in Gates of the Arctic National Park and Preserve, Alaska. Sheep were captured in March 1998, March 1999 and March 2000.

Capture	Sheep	Wgt.			Horn Length[+]		Annuli		Hindfoot	Body	Chest	Jaw	Neck	Tooth	General	Fate[c]
Date	ID	(kg)	Sex	Age*	Right	Left	Right	Left	Length[+]	Length[+]	Girth[+]	Length[+]	Circ.[+]	Wear	Condition	
3/24/98	801	39	F	7	27.0	27.0	6.0	6.0	26.4	147.0	91.0	20.2	36.0	Very little		Dead
3/24/98	802	49	F	7	24.0	23.0	6.0	6.0	27.9	152.0	98.0	26.4	41.0	Very little		Dead
3/24/98	803	53	F	7	25.0	23.5	6.0	6.0	26.2	158.0	96.0	18.4	39.0	Moderate		?[b]
3/24/98	804		M	10			9.0[a]	8.0[a]						Moderate		Dead
3/24/98	805		M	7			6.0	6.0						None		Dead
3/25/98	806		F	7	32.0	29.5	6.0	6.0					43.0	Moderate		Dead
3/25/98	807		F	5	26.0	27.0	4.0	4.0					38.0	Slight		Alive
3/25/98	808		F	6	21.5	18.5	5.0	5.0					38.0	Very little		Alive
3/25/98	809		F	4	18.5	17.8	3.0	3.0					38.0	None		Dead
3/25/98	810		M	8	75.0	75.0	7.0	7.0					49.0	Moderate		Alive
3/25/98	811		F	4	25.0	21.0	3.0	3.0					41.0	None		Alive
3/25/98	812		F	8	28.0	27.0	7.0	7.0					44.0	Moderate		Dead
3/25/98	813		F	9	28.0	26.5	8.0	8.0					46.6	Moderate		Dead
3/26/98	814	56	F	9	34.0	32.0	8.0	7.0		153.0	106.0		47.0	Heavy		Alive
3/26/98	815		F	8	24.0	22.0	7.0	7.0		147.0			42.0	Moderate		Dead
3/26/98	816	59	F	8	27.5	28.0	7.0	7.0		147.0	103.0		42.0	Moderate		Dead
3/26/98	817	48	F	9	30.0	29.0	8.0	7.0		150.0	95.0		40.0	Moderate		Dead
3/26/98	818	46	F	10	27.0	26.0	9.0	9.0		140.0	98.0		45.0	Very worn		Dead
3/26/98	819		F													?
3/27/99	820	41	F	4	19.0	14.5	3.0	3.0	28.5		94.0		39.5	Light	Good	?[b]
3/27/99	821	52	F	10	27.5	30.5	9.0	9.0	27.5		105.0		41.0	Heavy	Thin / boney	Dead
3/27/99	822	57	F	7	25.3	25.0	6.0	5.0	29.5		96.5		41.0	Moderate to heavy	Thin / boney	Alive
3/8/00	823	67	M	8	54.2	57.0	8.0	8.0	29.5		109.0		56.0	Light	Very good	Dead
3/8/00	824	66	F	9	26.0	25.5	8.0	9.0	29.0		128.0		43.0	Moderate	Excellent	Alive
3/8/00	825	48	F	6	24.2	15.5	6.0	6.0[a]	27.5		99.0		40.0	Light	Excellent	Alive
3/8/00	826	68	M	9	64.0	64.0	8.0	8.0	32.0		112.0		53.0	Light	Excellent	Alive
3/8/00	827	59	F	7	24.0	26.5	6.0	7.0			104.5		44.0	Light	Excellent	Alive

* Age at capture. Sheep were aged by counting horn annuli as described by Geist (1971).
[a] Broomed horn tips. [b] Radiocollar failure. [c] Survival as of 18 March 2002.
[+] Lengths in cm

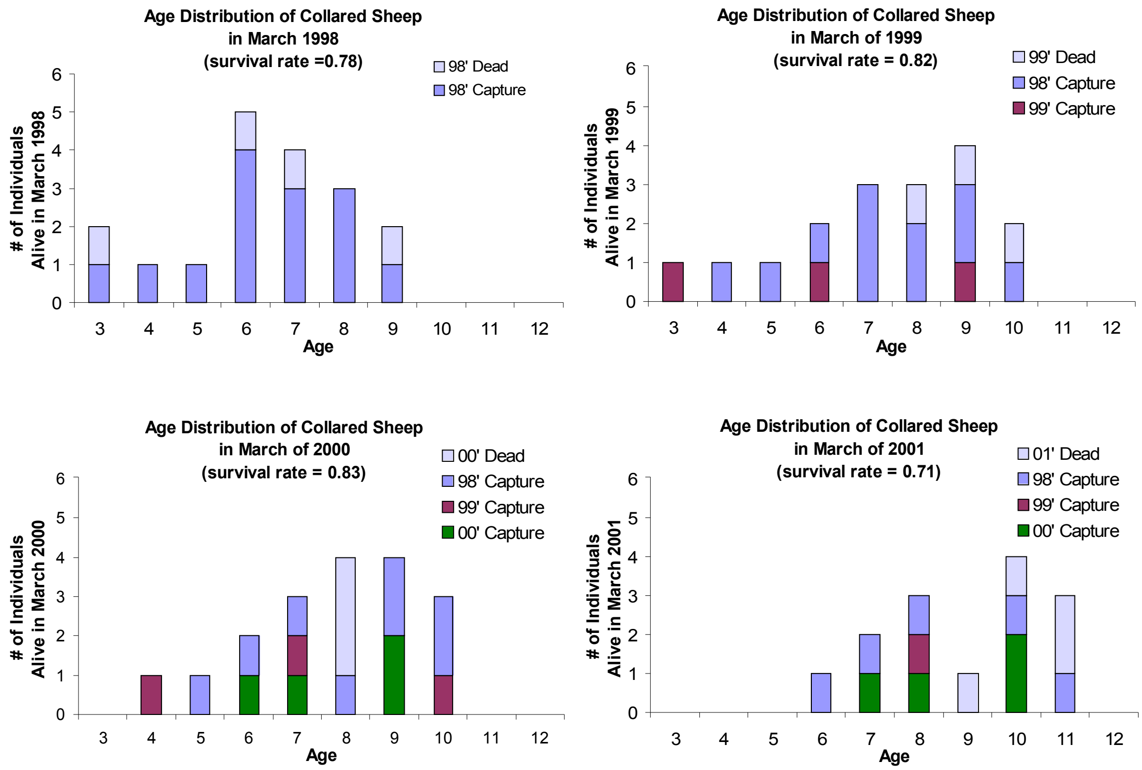

Fig. 2. Age distribution of radiocollared Dall's sheep near Anaktuvuk Pass, Alaska in March of 1998, 1999, 2000 and 2001. Annual survival rates were calculated for each of the four years of the study. Sheep that were alive at the end of the year are solid bars and sheep that died during the year are hashed bars (year runs from March to March). The living sheep (solid bar) are color coded by year of capture.

<u>Survival</u>

Between 1998 and 2001, there were 14 sheep mortalities from a total of 27 radiocollared sheep (Fig. 1). Most sheep mortalities in this study were not investigated soon enough following death to determine cause. One of the five mortalities in which probable cause of death could be ascertained was a ewe that died in the Till Creek drainage, apparently mired in deep snow. This animal was necropsied by University of Alaska Fairbanks veterinarian, John Blake and cause of death was capture myopathy, a muscle degeneration caused by stress. Whether this stressed was caused by the radiocollaring capture operation or from foundering in deep snow is uncertain. Because the animal died within three weeks of being captured, this mortality was considered to be capture related and this animal was excluded from subsequent analysis. Large quantities of blood in the snow near a second sheep indicate this animal was killed following a struggle but a specific predator could not be identified. A third collar was unbolted and found under a rock indicating this animal had been harvested by a person. The final two sheep appear to have been killed by wolverines because both sheep were found soon after death with large quantities of blood in the vicinity and only wolverine track and sign in the vicinity. In one of these cases, a wolverine was observed near the dead sheep.

Mean (±SE) annual sheep survival rate over this four-year study was 0.78 (±0.027) (Fig. 3). In 1998, sheep mortality tended to be dispersed across age classes. In subsequent years, older sheep tended to die more frequently than did the younger age classes and this trend was particularly strong in 1999 and 2001. Hoefs and Cowan (1979) calculated a survival rate of 80% for adult ewes in Kluane National Park in a stable Dall's sheep population. Simmons et al. (1984) estimated an average annual survival rate for adult ewes in the Mackenzie Mountains in northwestern Alaska and in Denali National Park, Alaska of 85%. The observed survival rate in this study is therefore comparable to these other populations. Reported sheep mortality is low between age 2 and 8 and increases sharply thereafter (Nichols and Bunnell 1999). In wild populations, Dall's sheep older than 13 years of age are rare (Nichols and Bunnell 1999). Yearly mean age of radiocollared sheep during the four years of this study were 6.4, 7.3, 7.7 and 9.0 years of age (for the years of 1998, 1999, 2000, and 2001, respectively).

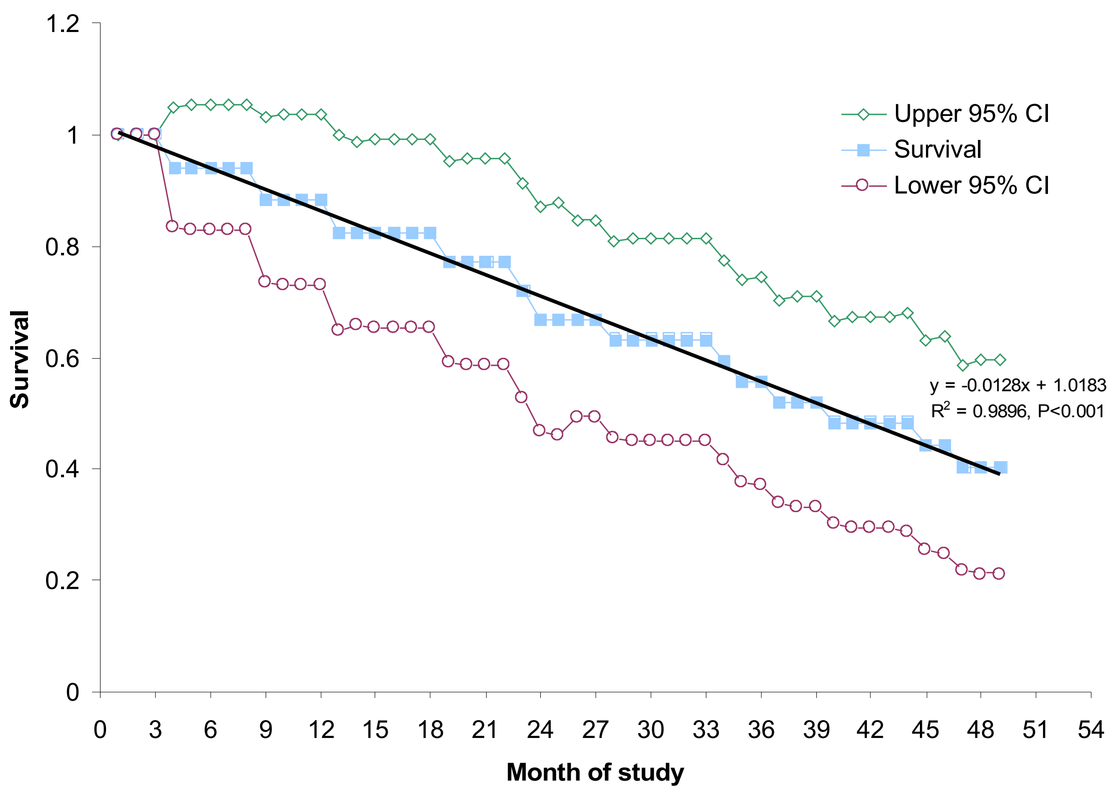

Fig. 3. The Kaplan-Meier survival function with 95% confidence intervals for Dall's sheep near Anaktuvuk Pass, Alaska from March 1998 (month 1) through March 2002 (month 49). The annual number of alive radiocollared Dall's sheep in this study varied between 18 and 10.

Dall's sheep deaths occurred regularly throughout this study. The Kaplan-Meier survival function demonstrates a relatively smooth decline in survival (Fig 3). This smooth decline illustrates that, although weather was potentially a factor in Dall's sheep survival during this study, no season or year stands out as being substantially different from others (Murie 1944, Whitten 1975, Burles and Hoefs 1984, Burles et al. 1984, Watson and Heimer 1984). A linear regression model fitted to the observed survival rate also supports this observation because survival rate was strongly correlated to monthly progression in this study (Fig. 3).

II. Sheep Movements

Methods

Animal locations were obtained using a fixed-wing aircraft (Piper PA-18 Super Cub or a Cessna 185) and logged in the aircraft geographical positioning system (GPS). For each observed radiocollared animal the date, coordinates, time, size of the group with the collared animal, group age-sex composition, and terrain characteristics were recorded. In addition, the distance the sheep were from escape terrain, and the elevation of sheep were estimated. Terrain considered "escape terrain" was subjectively determined based on ruggedness and slope. In some instances, particularly in the winter, visual observations of sheep were not possible. In these situations, only a general location for the sheep was recorded. Radiotracking flights were scheduled twice monthly but we experienced great difficulty maintaining this schedule due to the unpredictability of weather in the central Brooks Range. Flights were spaced a minimum of five days apart to avoid problems with independence with consecutive locations (White and Garrott 1990).

For Dall's sheep ewes, the presence of an associated lamb was recorded. Ewes were considered to have lambed in a given year if they were either observed alone with a lamb or, if associated with a group, if the lamb/ewe pair appeared to be shadowing each others movements. Estimates of lambing success presented in this report are conservative because no efforts were made to coordinate radiotracking flights with the initiation of the lambing season. Therefore, lamb mortalities that occurred soon after birth were not be detected. In addition, if sheep were observed in a large group, minimum time was spent separating animals into specific ewe/lamb pairs. Local criticism of this project focused on the potential negative effects of radiotracking overflights on sheep and therefore, time spent flying over individual sheep was minimized.

All Dall's sheep locations were entered into a Geographic Information System (GIS) for data management (ArcView GIS version 3.3, Environmental Systems Research, Inc. [ESRI], Redlands, California). This GIS system, along with the Animal Movement Analyst Extension (Hoogie and Eichenlaub 2000) was used to determine home range size for individual sheep and to examine seasonal ranges. Home ranges were only determined for sheep with 20 or more locations. Two estimators of home range were calculated. The minimum convex polygon (MCP) is the most commonly used estimator of home range size (White and Garrott 1990, Powell 2000) and is therefore presented to allow for comparison to other studies. For kernel analysis I used a fixed kernel with a smoothing factor calculated using least-squares cross-validation (LSCV; Worton 1995). Utilization distribution of sheep was assumed to be within the 95% contour and core use was considered to be within the 50% contour. ArcView was used for map production and graphical interpretation of data such as home range overlap. Dall's sheep distribution within the study area was examined during times of the year that corresponded to periods assumed to be important to the life history of the species. Although some authors define as many as six seasonal ranges for mountain sheep (Geist 1971), I chose to investigate five; spring (lambing), summer, fall, early winter (rut), and winter. Lambing in Dall's sheep occurs from May through the early part of June (Rachlow and Bowyer 1998, Nichols and Bunnell 1999). During summer months (July and August) plant production may influence sheep distribution. By September, production in most plants in the Brooks Range has ceased and factors other than green forage may influence sheep distribution. Rut was assumed to occur during November and December (Geist 1971, Nichols and Bunnell 1999). Following the rut, I assumed sheep moved onto winter ranges.

Radiotracking pilots for this study were Don Glaser, Sandy Hamilton, Dennis Miller, Buster Points, Jim Rood, Hollis Twitchell and Marty Web. Observers include Rachel Brubaker, Jane Bryant, John Burch, Melanie Cook, Nikki Guldager, Mike Haubert, Jim Lawler and Merry Maxwell.

Analysis of radiotracking data for collared animals included presence of lamb, mean group size (during the duration of study and by season), mean elevation (during the duration of the study and by season), mean distance to escape terrain, percent of time observed in mixed sex groups, minimum convex polygon home ranges, 95% and 50% contours for kernel home ranges, and maximum distance across home range (using MCP). Analyses used mean values from individual sheep and were restricted to animals with ≥ 20 locations. Because percentage data typically has a binomial rather than a normal distribution (Zar 1996), percentage data was arcsine transformed prior to analysis to avoid problems with data distribution. Because individual animals were the sampling unit, repeated measures general linear models (von Ende 1993, Zar 1996) were used to examine the relationship of season (within subject factor) and sex (between subject factor) on mean group size, mean elevation mean distance to escape terrain and the percentage of time spent in mixed sex groups. In this report I present repeated measures ANOVA results. Data sets used in repeated measures analysis were examined to ensure they met the sphericity assumption with the Mauchly sphericity test (von Ende 1993). When this assumption was not met, the degrees of freedom of the F statistic was adjusted with a Greenhouse-Geisser estimator (von Ende 1993). To examine biases from differing sample sizes, linear regression models were used to examine the relationship of home range sizes with the number of relocations for sheep with 20 or more relocations. Differences in home range sizes between male and female Dall's sheep were investigated using two-tailed *t*-tests. Results of all statistical analyses were considered significant if $P \leq 0.05$.

Results and Discussion

Sixty nine radiotracking flights were completed between 1998 and 2001. Not all sheep were located on every flight. Each sheep was located a mean of 44 times. Although sheep were located throughout the year, some seasons and animals are better represented than others (Table 2). Twenty one out of 26 radiocollared sheep were located on ≥ 20 occasions. The length of time between sequential radiotracking flights has varied greatly (range of 6-69 days) and therefore, estimates of movement distances and rates are of no value.

Table 2. Seasonal distribution of relocations for Dall's sheep radiocollared in Gates of the Arctic National Park and Preserve, Alaska from March 1998 through March 2002.

Sheep #	Winter	Lambing	Summer	Fall	Rut
801	18	10	7	8	5
802	2	5	2	4	1
803	7	5	1	4	2
804	7	5	2	4	2
805	20	11	7	9	5
806	18	13	6	7	4
807	24	15	11	10	5
808	25	15	11	11	5
809	2	5	1	1	0
810	25	15	11	10	5
811	25	14	11	11	5
812	0	1	0	0	0
813	16	13	8	9	5
814	23	11	11	8	5
815	20	13	10	10	5
816	8	8	6	6	2
817	10	9	6	6	2
818	7	5	2	5	3
820	15	7	7	5	3
821	16	7	8	5	3
822	18	7	8	6	2
823	3	2	1	0	0
824	12	3	5	4	2
825	9	2	4	4	2
826	12	4	4	4	2
827	10	3	5	4	2
Total	352	208	155	155	77

During 1998, 71% of radiocollared ewes were observed with a lamb (Table 3). This percentage dropped in 1999 to 62% and dropped again in 2000 to 50%. This trend was reversed in 2001 when 64% of the radiocollared ewes were observed with a lamb. The mean (±SE) number of ewes estimated to produce lambs was 62 (±4.4)% during the four years of this study.

Dall's sheep were observed to occur in mean (±SE) group sizes of 7 (±0.50) sheep. Group size varied by season ($F_{[1.9, 18]} = 7.44$, $P = 0.002$) and by gender ($F_{[1, 18]} = 17.07$, $P = 0.001$; Fig. 4). Group sizes were largest during lambing and smallest during the rut and winter. Ewes (n=18) occurred in larger groups more often than did rams (n=4) and this result was most apparent during lambing season. The interaction of group size and gender was not significant ($F_{[1.9, 18]} = 2.53$, $P = 0.096$).

Table 3. Summary statistics for individual Dall's sheep gathered during radiotracking flights in Gates of the Arctic National Park and Preserve, Alaska 1998 –2002.

Sheep #	Year Capt.	Avg. Group size	Avg. Elev. (m)	Lamb Year[a]	Lamb Possib.[b]	Max. Dist (km)[c]	MCP (km^2)[d]	95% Kernel (km^2)	50% Kernel (km^2)	Sample (*n*)
801	98	5	1341	98, 00	3	13.9	70.9	83.3	11.6	47
802	98	13	549	98	1					14
803	98	11	945	98	1					19
804*	98	3	884			12.7	51.5	70.2	6.4	20
805*	98	4	1158			15.8	85.3	65.3	10.9	52
806	98	8	1280	98, 99	4	14.5	85.9	65.0	6.6	49
807	98	6	1219		4	17.0	128.1	78.0	6.3	67
808	98	9	1250	98, 00, 01	4	14.4	50.2	54.1	7.6	69
809	98	6	853		1					8
810*	98	4	1311			11.7	47.5	13.8	1.3	69
811	98	7	1311	98	4	15.2	64.2	21.4	3.5	68
813	98	9	1341	98	3	13.0	66.3	26.6	3.5	51
814	98	7	1249	98, 99, 01	4	16.6	121.1	140.2	27.3	61
815	98	5	1310	99, 01	3	13.4	67.9	72.5	9.2	61
816	98	7	1372	98, 99	2	14.5	69.4	91.5	14.0	30
817	98	8	1341	99	2	12.6	60.5	73.3	12.0	33
818	98	7	1341	98	1	10.5	52.5	48.5	4.9	22
820	99	10	1371	99, 01	3	14.6	102.7	102.8	16.1	37
821	99	10	1341	99, 00	3	14.0	54.0	38.8	3.7	38
822	99	7	1463	99, 00, 01	3	7.4	63.4	63.2	9.0	44
823*	00	5	1433							6
824	00	9	1280	00	2	14.1	56.9	44.6	9.1	29
825	00	10	1372	00, 01	2	12.2	48.2	66.5	6.9	24
826*	00	3	1372			18.6	84.9	113.6	21.7	29
827	00	9	1311	00, 01	2	12.6	89.2	129.9	19.8	26

* Ram

[a] Number indicates the year a ewe was observed with a lamb.

[b] Number of lambing seasons radiotracked..

[c] Maximum distance in a straight line across an animals home range.

[d] Area encompassed by a minimum convex polygon drawn around relocation points.

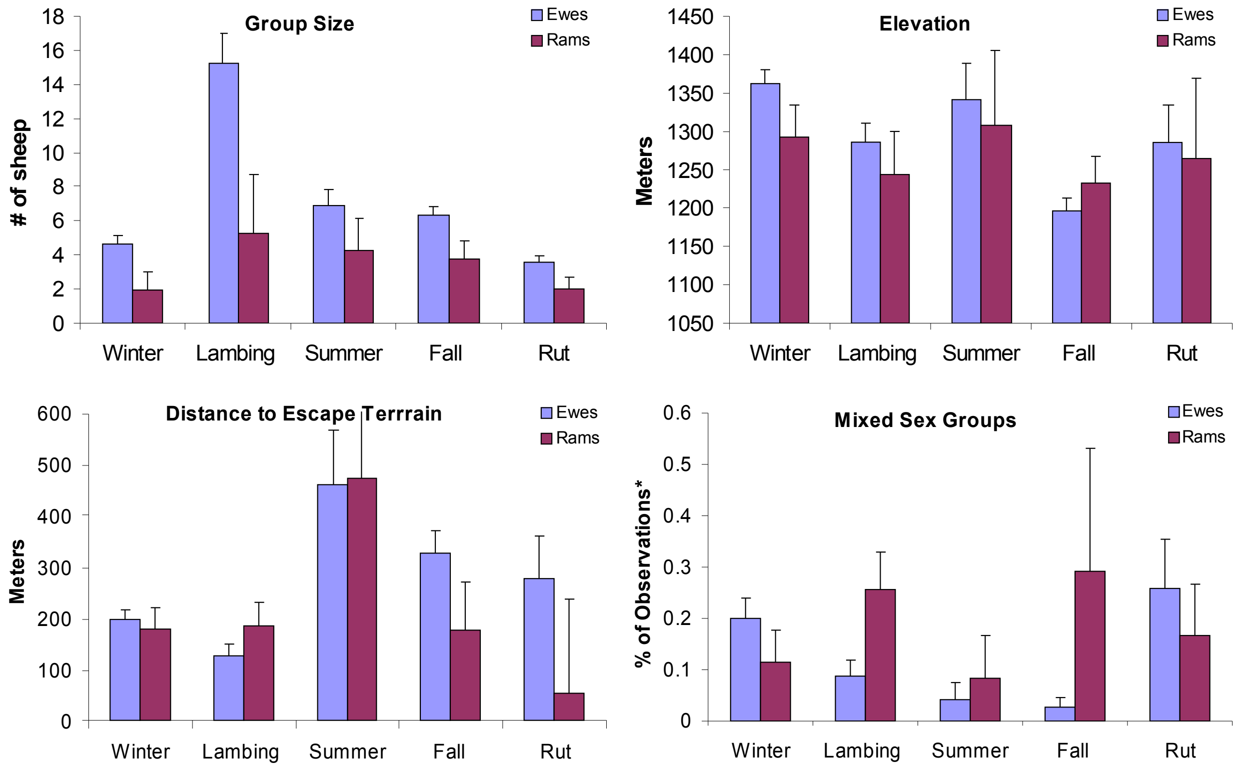

Fig. 4. Group size, elevation, distance to escape terrain and the percentage of time the animal was observed in a mixed sex group for Dall's sheep in Gates of the Arctic National Park and Preserve, Alaska 1998-2002. Values presented are means (+SE) for ewes (*n*=18) and rams (*n*=4).

Mean (±SE) yearly elevation occupied by radiocollared sheep was 1296 (±24.9) m (4252 [±81.8] ft; Table 3). Sheep tended to select higher locations in winter and summer, and lower elevation during the fall in comparison to other times of the year but this result was not statistically significant ($F_{[2.6, 20]} = 1.45$, $P = 0.241$; Fig 4). Likewise, there was a tendency for ewes to choose higher locations than rams but this was not significant ($F_{[1, 20]} = 0.415$, $P = 0.527$). There were no significant gender by season interaction ($F_{[4, 17]} = 0.793$, $P = 0.546$; Fig. 4).

Sheep observed during this study were a mean (±SE) distance of 247.4 (±36.5) m (810 ft. [±119.8] away from escape terrain. Although there were substantial differences in seasonal mean differences (Fig. 4), there was also substantial variation within seasons. As a result, there were no statistical seasonal differences in distances sheep were observed from escape terrain ($F_{[2.2, 20]} = 2.903$, $P = 0.062$). Rams and ewes did not differ in how far they were observed away from escape terrain ($F_{[2.2, 20]} = 2.903$, $P = 0.062$; Fig. 4).

Radiocollared Dall's sheep were observed in mixed sex groups a mean (±SE) of 16 (±0.04)% of the time (Fig. 4). Rams were observed to be in mixed sex groups most commonly in the fall and ewes were observed most commonly in mixed sex groups during the rut. Seasonal differences in the percentages of sheep in mixed sex groups were not statistically significant ($F_{[1.9, 20]} = 0.918$, $P = 0.405$). Rams tended to be in mixed sex groups more often than did females (20[±7]% and 0.12[±3]% of observations, respectively) but this result was not significant ($F_{[1, 20]} = 0.762$, $P = 0.393$). Some caution is advisable when interpreting this mixed sex data because many immature rams were undoubtedly classified as ewes. These misclassified young rams, if observed with mature rams, would inflate the number of observations of rams in mixed sex groups. Likewise, if these young rams were observed with a group of ewes, the entire group would be classified as ewes thereby deflating the number of observations of ewes in mixed groups. In addition, no consideration is given to the reproductive status of the ewes in these statistics. This consideration may be particularly important during lambing season. The combination of lambs and mature rams together in the same group was only observed a mean of 2 ($\pm$0.9)% of the time. Readers should also note that the sample size for rams is small (n=4).

When MCP was used to estimate home range size there was a slight tendency for area to increase with increasing numbers of relocations (Fig. 5) but this trend was not significant ($F_{(1, 19)} = 1.36$, $r^2 = 0.07$, $P = 0.257$). This tendency was not unexpected because the MCP home range estimate increases indefinitely with increasing numbers of relocations (Jennrich and Turner 1969, White and Garrott 1990). In contrast, when kernel analysis was used to estimate home range size, there was a tendency for size of home range to decrease with an increased number of locations (Fig. 5) but this trend was not significant for the utilization distribution (95% contour; $F_{(1, 19)} = 1.53$, $r^2 = 0.07$, $P = 0.231$) or the core use area (50% contour; $F_{(1, 19)} = 0.80$, $r^2 = 0.04$, $P = 0.382$). Therefore, these results indicate that 20 relocations of Dall's sheep were sufficient to achieve a reasonable estimate of home range size for both MCP and kernel analyses.

The range of values for utilization distribution of Dall's sheep defined by kernel analysis (95% kernel; 13.8-140.2 km^2 [5.3-54.0 mi^2]) was substantially wider than the values from MCP (MCP; 47.5 km^2 to 128.1 km^2 [18.3 mi^2 to 49.5 mi^2]) but means were similar with means ($\pm$SE) of 69.7 ($\pm$7.25) km^2 (26.9 [$\pm$2.80] mi^2) and 72.4 ($\pm$5.04) km^2 (28 [$\pm$1.95] mi^2) for kernel analysis and MCP, respectively (Table 3). Core use areas (50% kernels) were 8-20% of Dall's sheep's utilization distributions (Table 3). The mean ($\pm$SE) for core use areas was 10.1 ($\pm$ 1.44) km^2 (3.9 [$\pm$ 0.56] mi^2). There were no significant differences between males and females in size of home ranges for MCP ($t = 0.532$, df = 4, $P = 0.617$), utilization distribution ($t = 0.223$, df = 4, $P = 0.835$), or core areas ($t = 0.002$, df = 4, $P = 0.998$).

Considerable overlap existed between Dall's sheep home ranges on the east and west sides of the the John River (Fig. 6-8). Larger rivers and creek drainages in the Anaktuvuk Pass area however, appear to act as substantial barriers to Dall's sheep because no radiocollared sheep were observed to cross the John River or Kollutarak creek during this study. It should be noted however, that residents of Anaktuvuk Pass and commercial airline pilots that regularly fly over this area have observed Dall's sheep crossing these drainages (B. Miller, Wrights Air Service, personal communication). In general, there is good agreement in the distribution of home ranges when comparing MCP to the kernel utilization distribution.

Examination of seasonal distribution of Dall's sheep (Fig. 9-13) do not indicate large scale movements to distinct ranges. Certain areas appear to constitute Dall's sheep habitat year round. One area of particular interest that may be under represented by the radiotracking data is the area near Publituk, particularly during the lambing and summer season (Fig. 10 and 11). Although few of the radiocollared sheep utilized this area (sheep 809, 811 and 813) and those that did only did so for a short time, large numbers of ewe-like sheep with lambs were observed here. On 23 June, 1999 one group of 66 Dall's sheep was observed in this area (55 ewe-like sheep and 11 lambs). On 29 July 1999, three group of Dall's sheep were observed here within a quarter mile of each other. The first group contained 41 sheep (29 ewe-like sheep and 12 lambs), the second contained 45 sheep and the third contained 15 sheep. Unfortunately, due to turbulent flying conditions, it was only possible to get a sex and age composition in one of the three groups. Given this anecdotal information, this area appears to be an important lambing area, although not necessarily for those sheep radiocollared for this project.

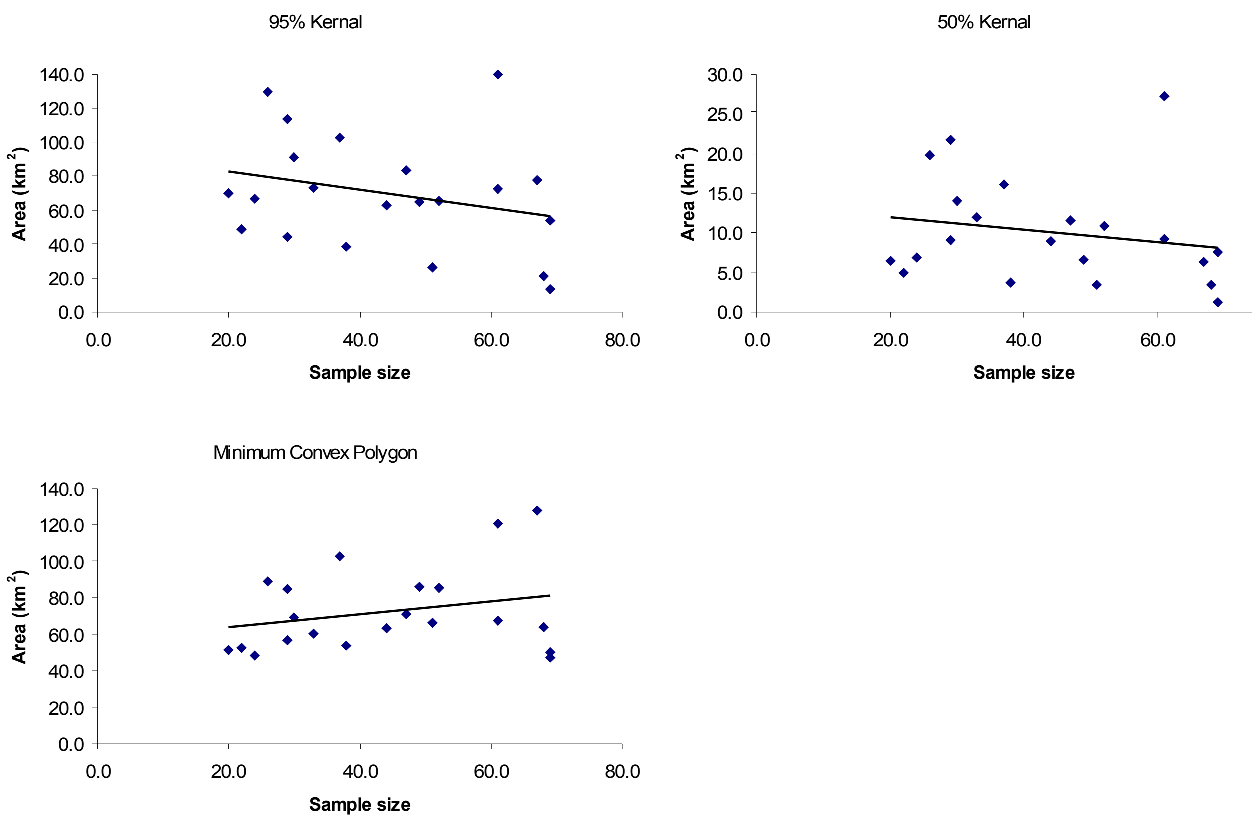

Fig. 5. The relationship of the number of relocations (sample size) for individual sheep and the size of the estimated home range (km^2). Only sheep with 20 or more relocations were included in the analysis. Trend lines indicate tendencies of home ranges to change with increasing numbers of samples but these tendencies were not significant for MCP or kernel analysis.

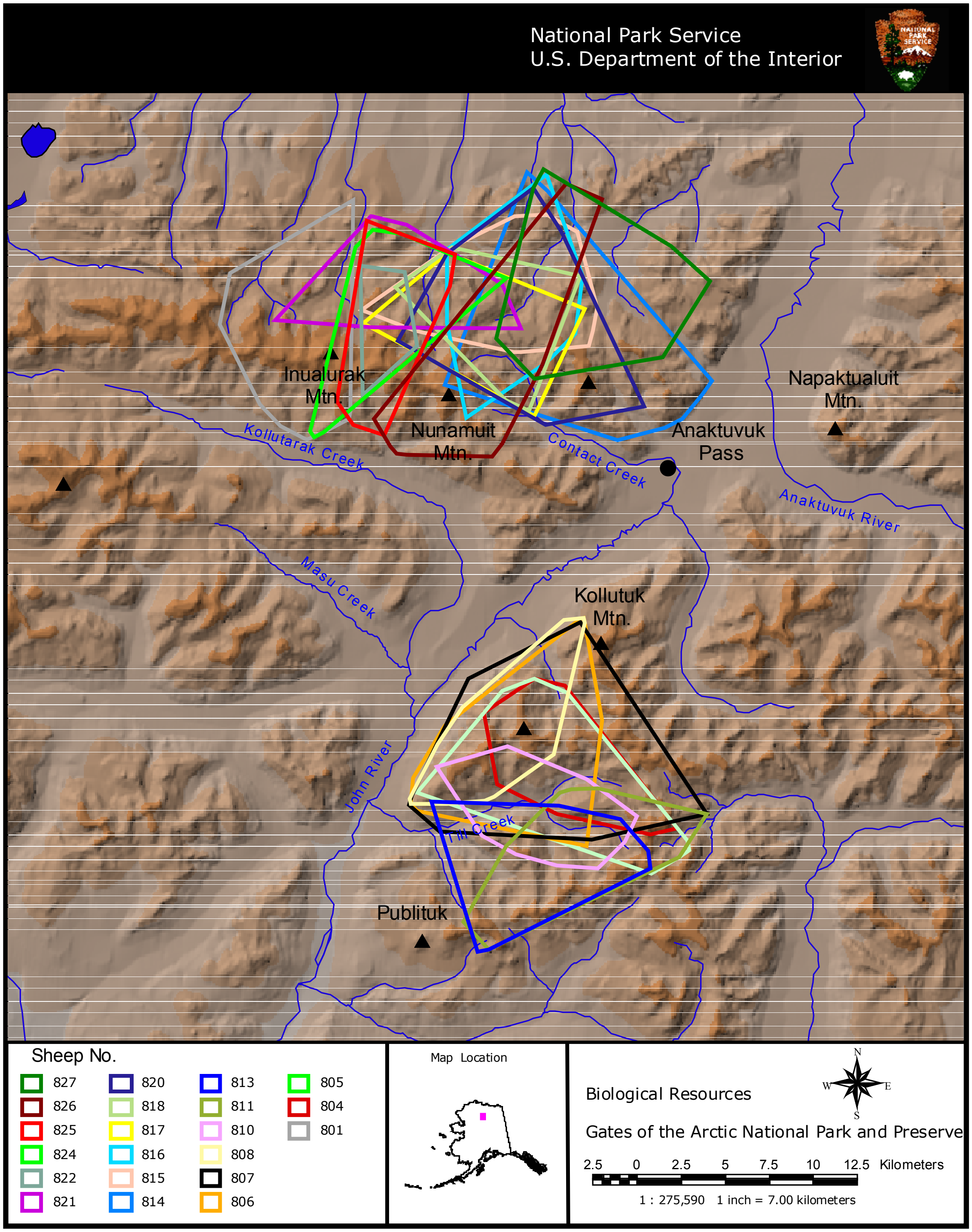

Fig. 6. Dall's sheep home ranges near Anaktuvuk Pass, Alaska from March 1998 to March 2002 determined using Minimum Convex Polygons.

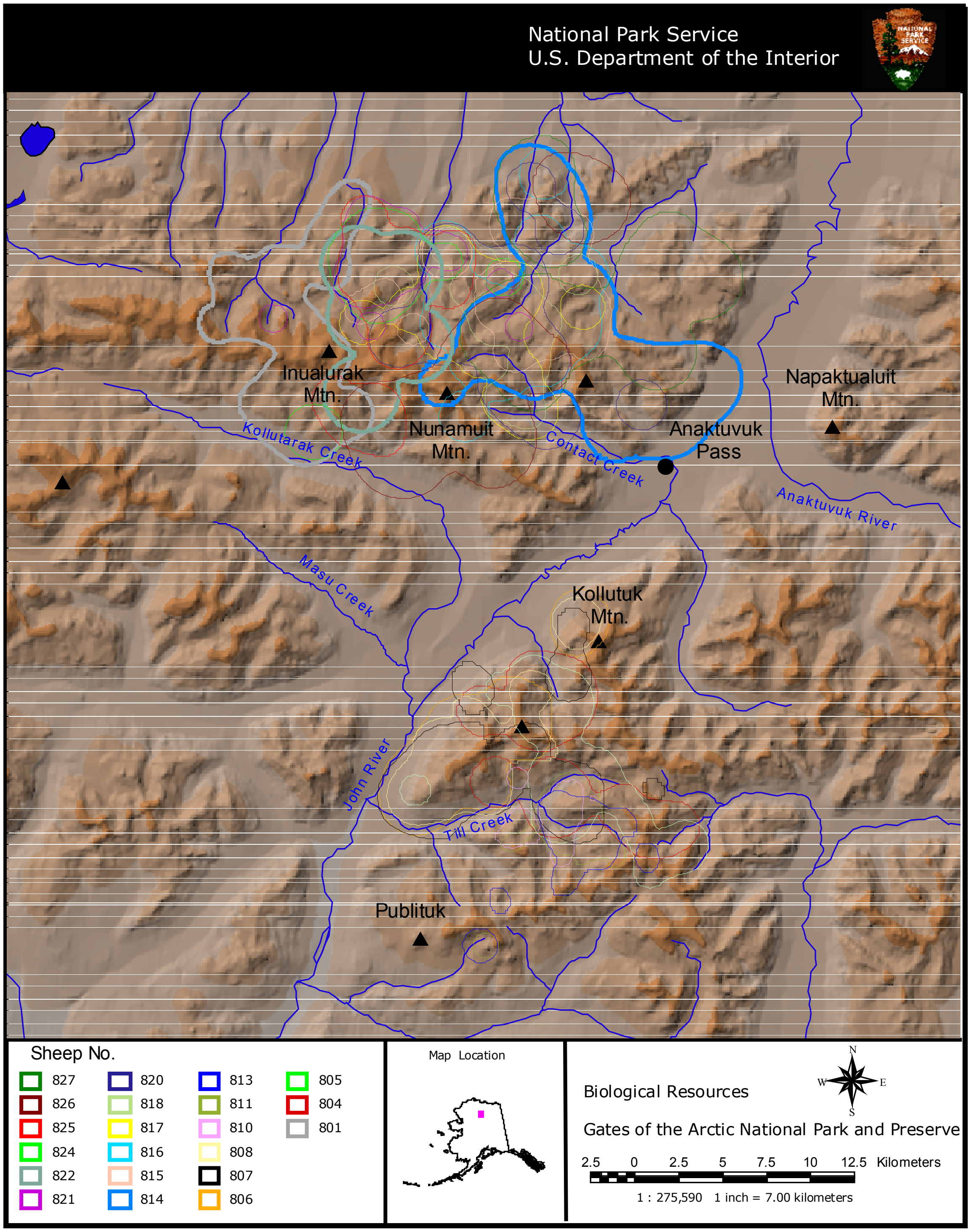

Fig. 7. Dall's sheep utilization distribution (95% kernel) near Anaktuvuk Pass, Alaska from March 1998 to March 2002.

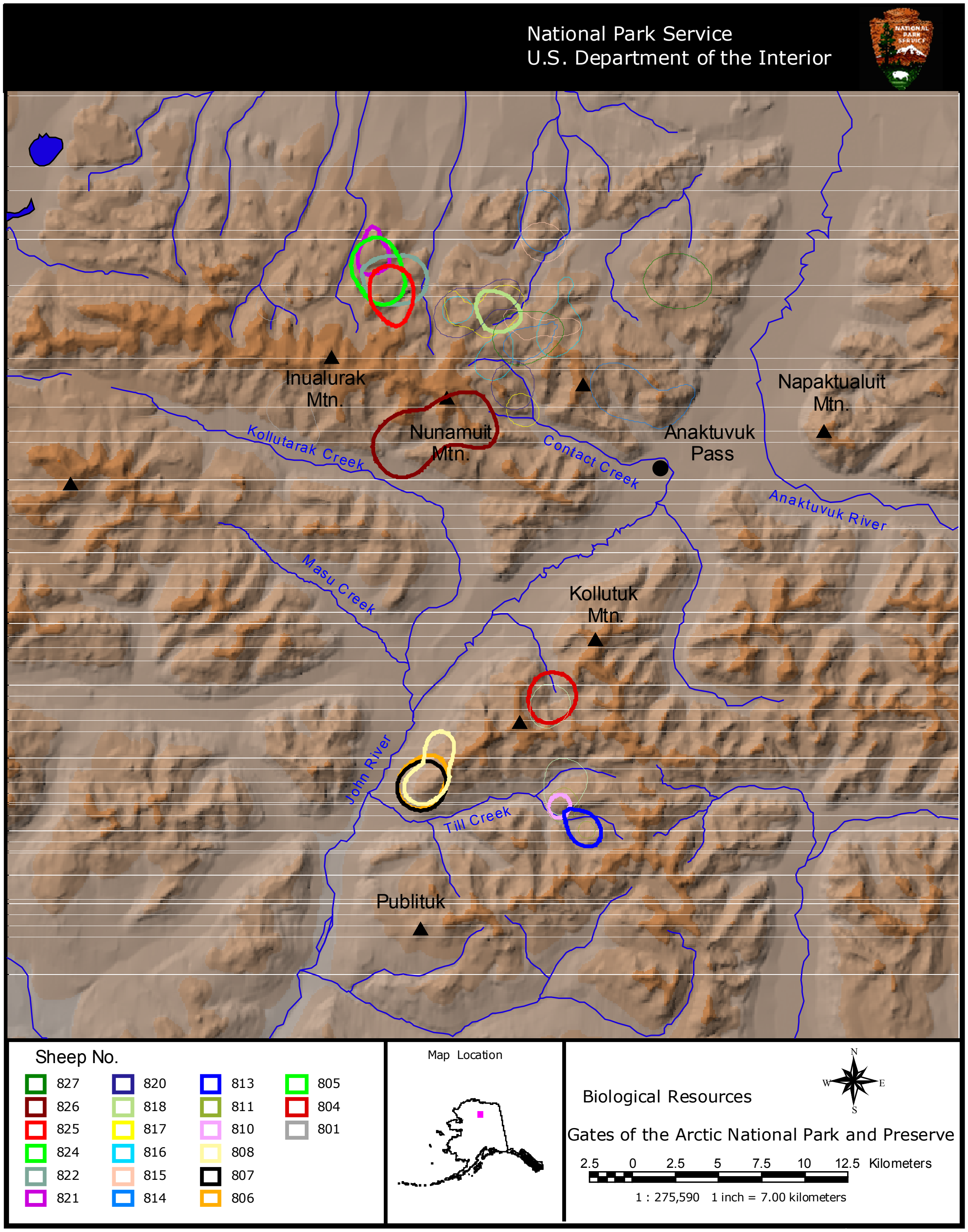

Fig. 8. Dall's sheep core use distribution (50% kernel) near Anaktuvuk Pass, Alaska from March 1998 to March 2002.

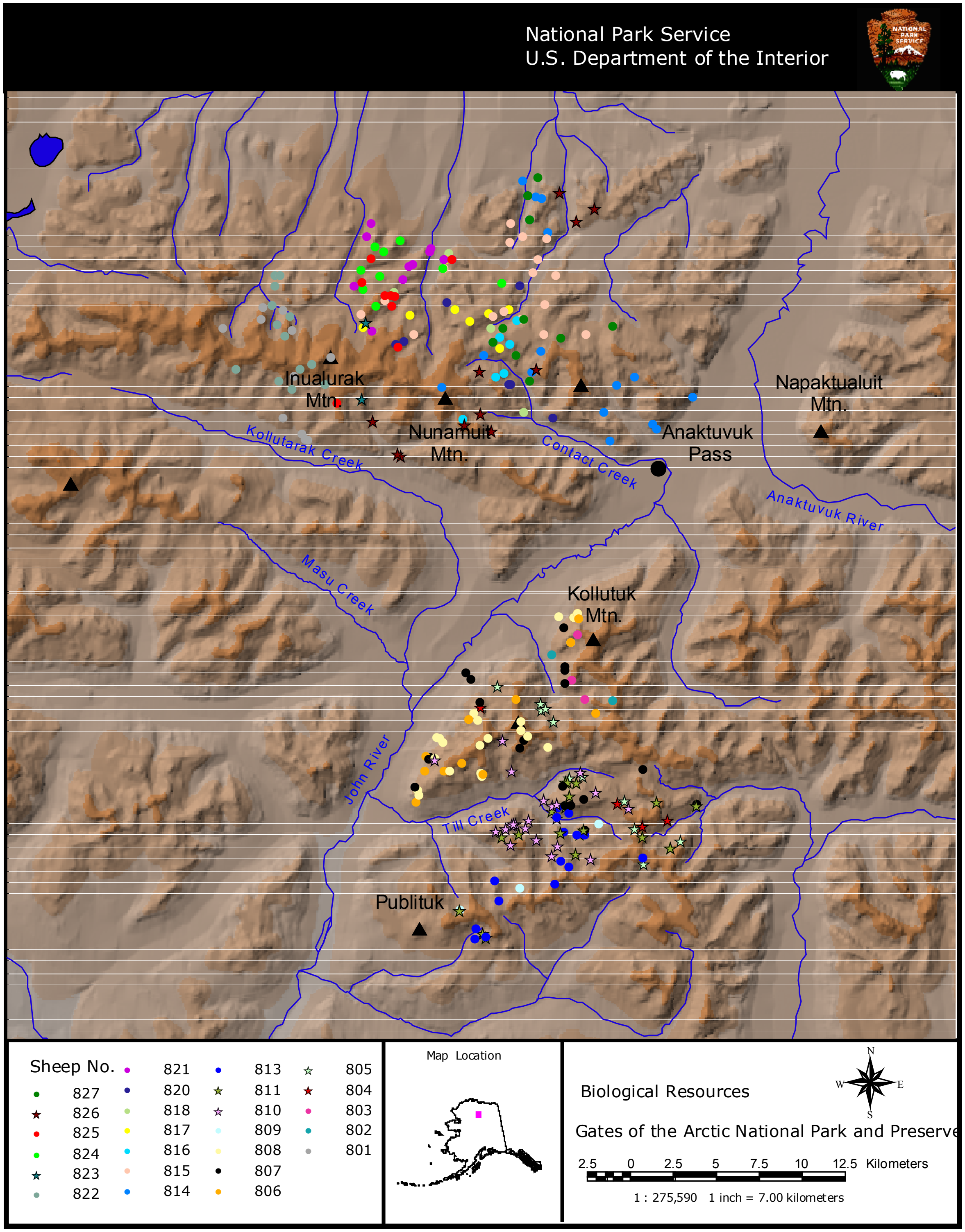

Fig. 9. Dall's sheep winter (January, February, March and April) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002. Starred animals are rams and dots are ewes.

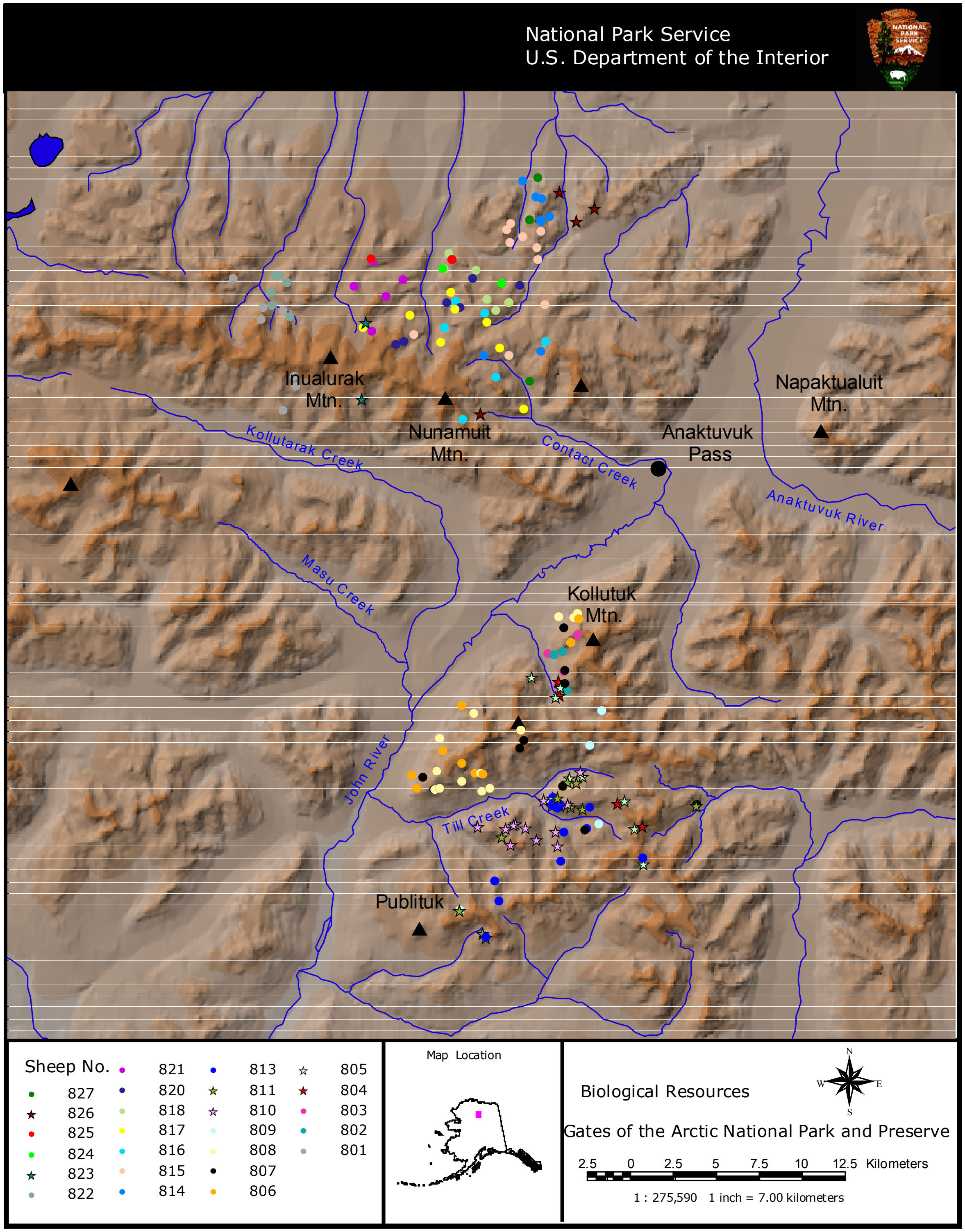

Fig. 10. Dall's sheep lambing (May and June) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002. Starred animals are rams and dots are ewes.

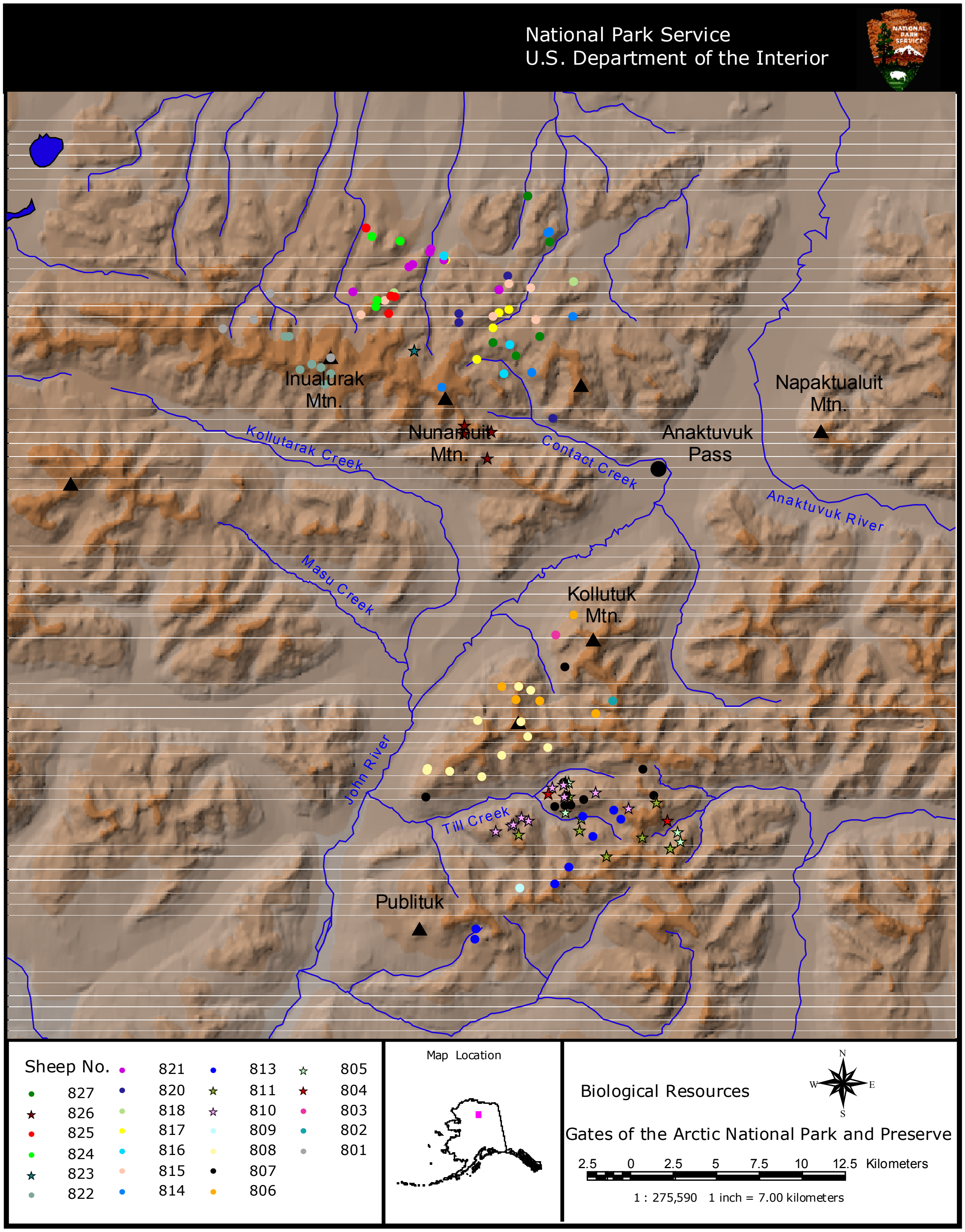

Fig. 11. Summer Dall's sheep (July and August) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002. Starred animals are rams and dots are ewes.

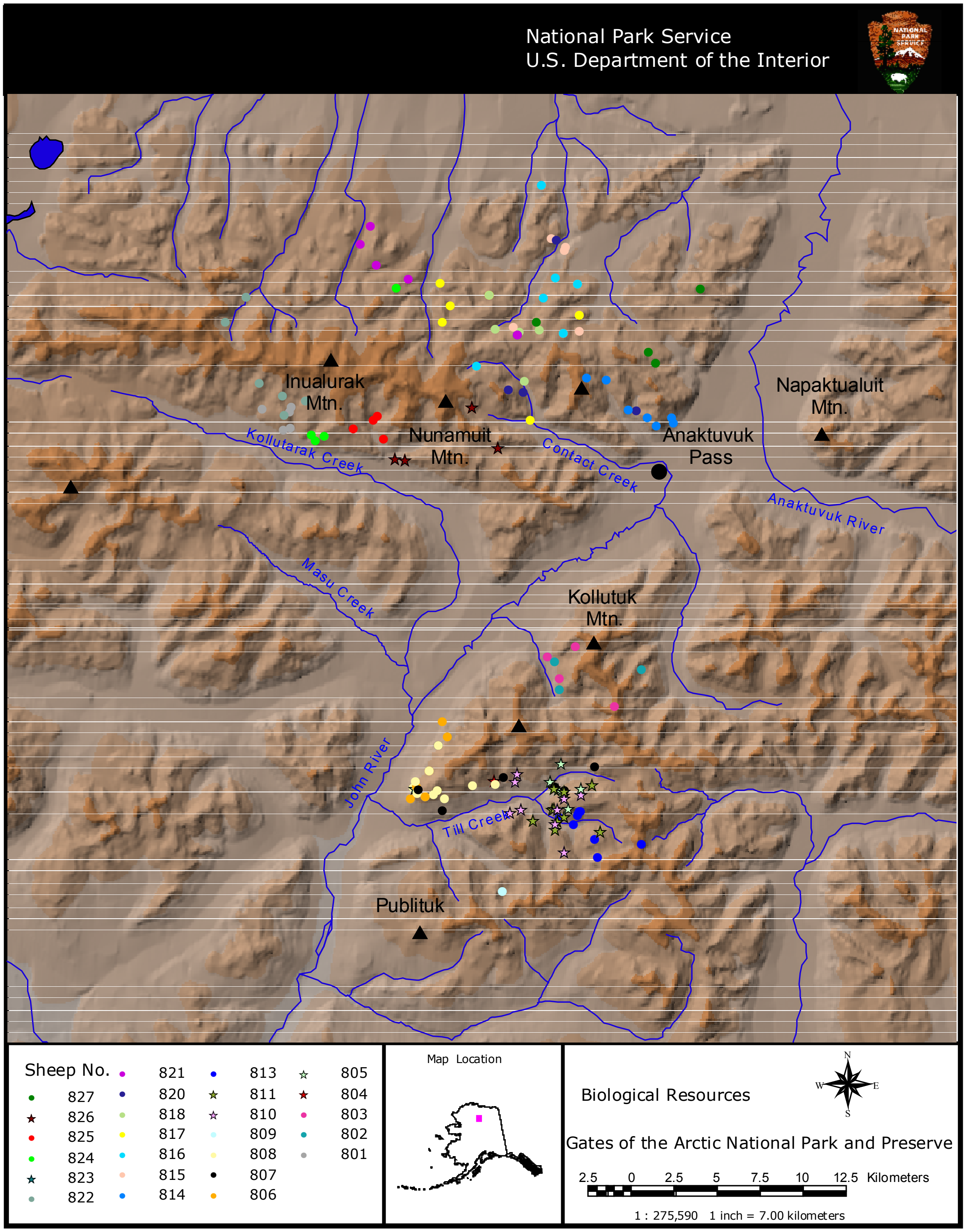

Fig. 12. Fall Dall's sheep (September and October) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002. Starred animals are rams and dots are ewes.

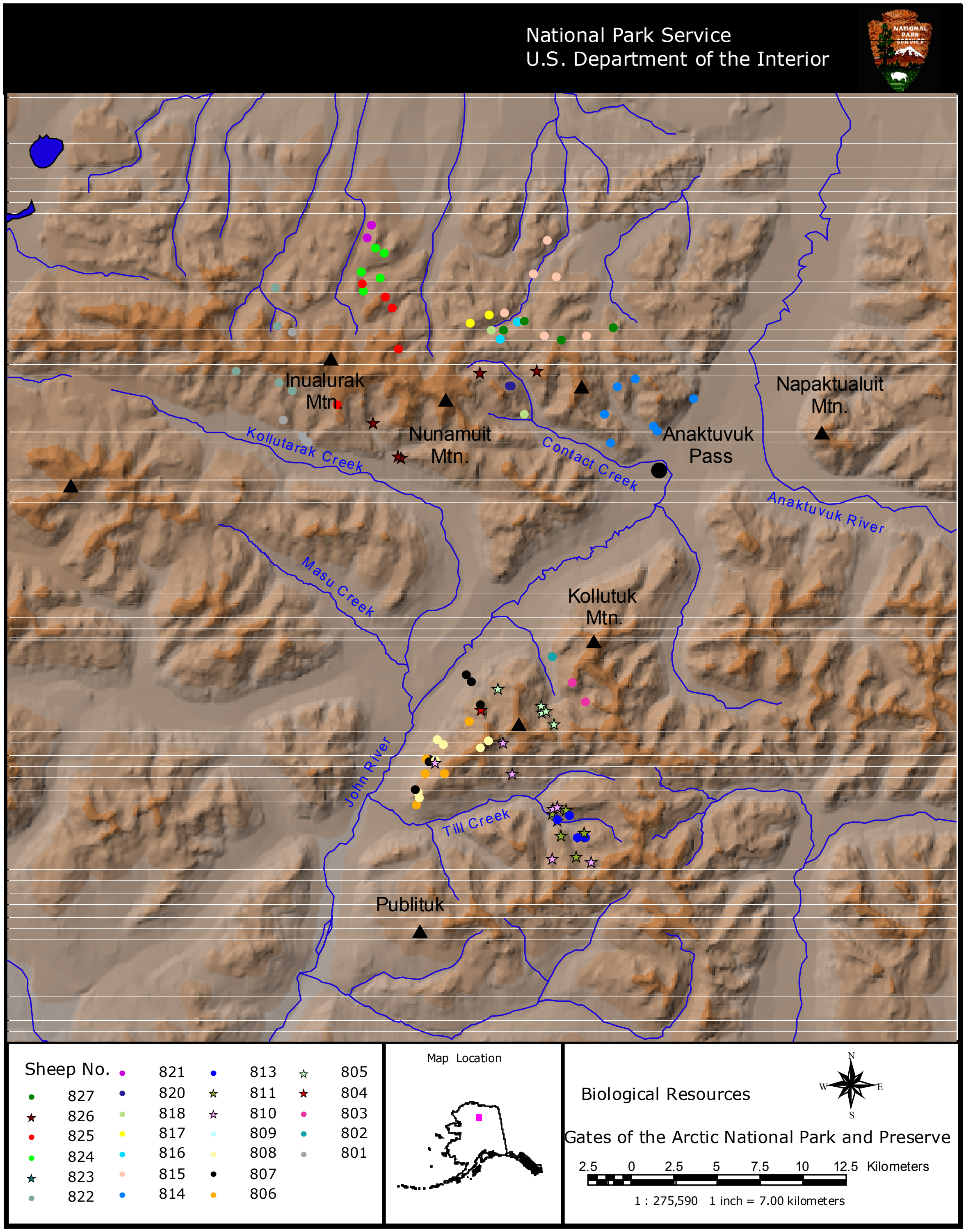

Fig. 13. Dall's sheep rutting (November and December) distribution near Anaktuvuk Pass, Alaska from March 1998 to March 2002. Starred animals are rams and dots are ewes.

III. Sheep trend count surveys in GAAR, 1998-2002

Aerial Survey

Annual population surveys provide insights into population trends, and changes in age and sex distribution of animal populations. Aerial surveys were conducted in June or July of 1998-2002 with the goal of tracking long-term population trends of Dall's sheep bands in this important subsistence area. Many factors went into the selection of the area surveyed (Fig. 14). This area can be surveyed in a reasonably short amount of time (three days) thereby minimizing the potential for animals to move between survey units. Included within the survey units are many of the subsistence hunting areas important to the people of Anaktuvuk Pass. The area chosen for this survey included the annual ranges of all the radiocollared sheep. Survey unit boundaries were those used in a sheep survey in 1996 (Brubaker and Whitten 1998), and were subdivisions used in previous surveys (Adams 1988, Singer 1984). Retention of old boundaries facilitated comparisons between surveys.

Methods

Sample units were surveyed at relatively low intensity with a fixed wing aircraft (Piper PA-18 Super Cub with pilot and one observer). The pilot and observer searched for sheep by contouring around terrain features in such a manner as to thoroughly cover an area. Typically this required two or three contour elevations around a given feature. Actual flight times per km^2 varied within and between sample units, depending on weather conditions and the complexity of the terrain, but probability of sighting a sheep was considered uniform throughout the survey. The aircraft circled groups of sheep as necessary to obtain accurate classification counts. Sheep were classified as rams, ewe-like, or lambs. Rams included all animals with > quarter-curl horns. The ewe-like category included rams with quarter-curl or smaller horns and all ewes. Lambs were sheep less than one year of age and were conspicuous because of their small size. Locations of sheep were marked on 1:63,360 scale USGS maps and numbers and classifications were recorded on a data sheet. Jim Rood was the survey pilot in 1998, Don Glaser was the survey pilot in 1999 and 2000, Marty Webb was the survey pilot in 2001, and Kevin Fox was the survey pilot in 2002. Jim Lawler served as the observer during all surveys.

Survey units delineated by previous workers were used to survey sheep (Fig. 14). These units provided an area that could be surveyed in a reasonable amount of time (mean = 52.7 min.), and yet were large enough (mean = 61.6 km^2 [23.8 mi^2]) that movement between units during the survey was thought to be negligible. Within individual study units however, Dall's sheep numbers showed considerable fluctuation (appendix 1). Evidence from radiocollared sheep indicated that sheep rarely crossed the larger drainages within the study area (the Kollutarak, Publituk and John Rivers; Figs. 6-8) and suggested a minimum of two subpopulations. Not all units were surveyed in every year. In those years when the entire survey could not be completed, the units that were surveyed varied. For these reasons, Dall's sheep populations trends near Anaktuvuk Pass were analyzed as two populations; units to the west of the town of Anaktuvuk Pass the Anaktuvuk River and John Rivers, and units to the east of these landmarks.

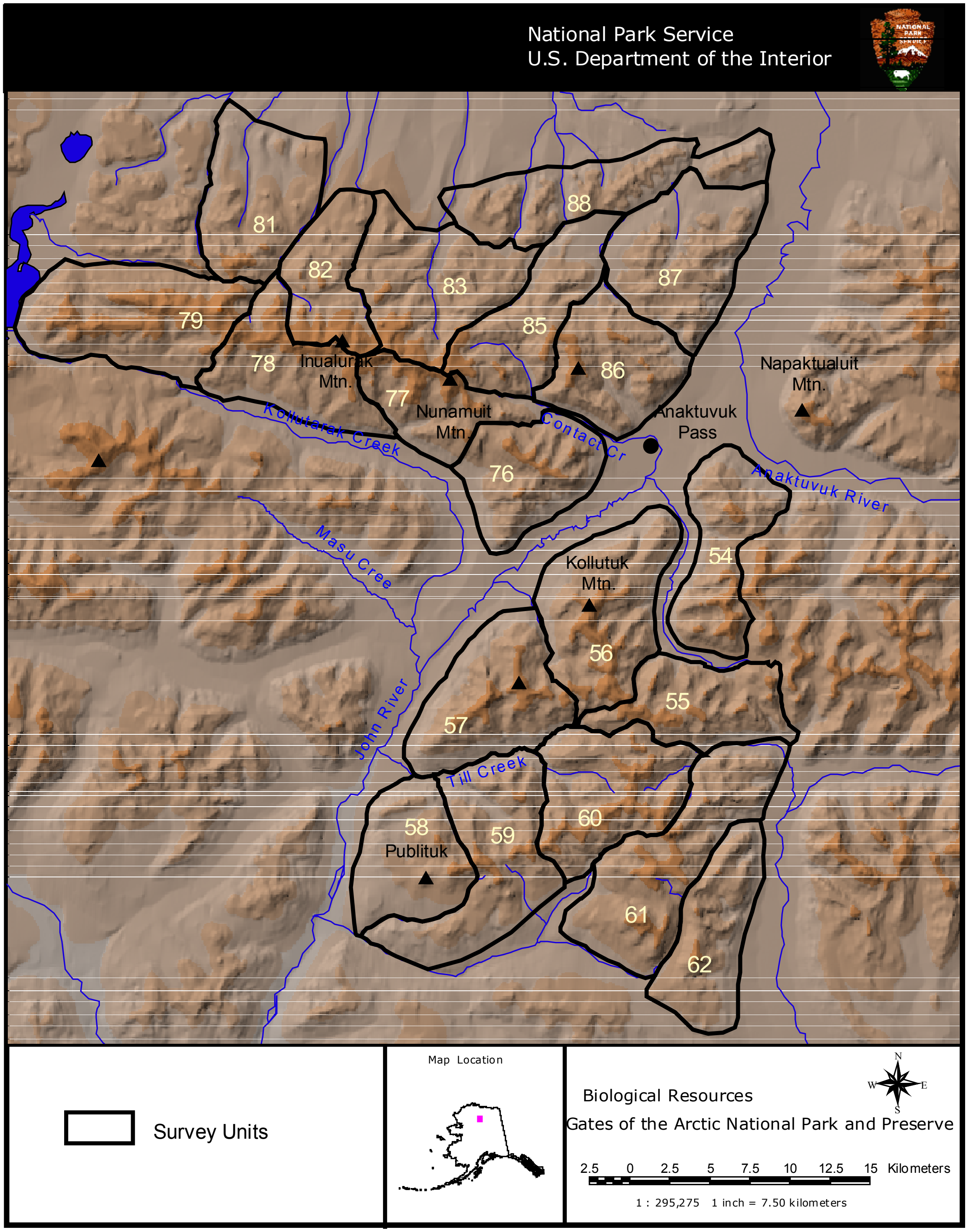

Fig. 14. Survey units used for aerial counts of Dall's sheep during June and July 1998-2002 near Anaktuvuk Pass, Alaska.

In all years, survey units were flown at an intensity where the observer and pilot felt that few sheep were being overlooked. Sampling effort (survey time) however, varied by year. The assumption that the number of rams, ewe-like sheep and lambs observed east and west of the Anaktuvuk and John River was not affected by sampling intensity was tested using linear regression (SPSS 10.1 1999). Only survey units that were surveyed all five years were included in this data set (4 out of 9 units on the east side of Anaktuvuk and 4 out of 11 units on the west side of Anaktuvuk).

Differences in densities of Dall's sheep to the east and west of Anaktuvuk Pass were examined with paired T-tests. The five-year trends in numbers of Dall's sheep rams, ewe-like sheep and lambs observed during surveys in the areas east and west of Anaktuvuk Pass were examined using linear regression. Because every survey unit was not surveyed every year, I used sheep densities rather than absolute numbers to test trend data.

Results and Discussion

Aerial surveys were conducted during the summer of 1998-2002 (appendix 1; Table 4). Survey conditions were good in 1998 and 2002 with good light conditions and light winds. In 1999 high winds prevented the completion of the survey. During 2000 wind, new snow and fog prevented the completion of the survey. Snow and fog was also problematic during the 2001 survey.

A total of 1,230 km^2 (475mi^2) were surveyed between 28 June and 1 July 1998 during 18.7 hours of flight time and a total of 386 sheep were observed. The 1999 total count was 186 sheep observed during 17 hours of flight time from 10 July through 13 July but only 1093 km^2 (422 mi^2) were surveyed. In 2000, the total count was 460 sheep from 29 June to 1 July in 12.7 hours of flight time and 837 km^2 (323 mi^2) were surveyed. The total number of sheep observed from 2 – 4 July 2001 was 285 in 12.9 hours of surveying covering 798 km^2 (308 mi^2). From 15 – 18 June 2002, the entire 1230 km^2 (475 mi^2) survey area was again covered in 17.6 hours of flying and 392 sheep were observed.

Age and sex composition during the 1998 survey was 26 lambs:100 ewe-like sheep and 27 rams:100 ewe-like sheep. During the 1999 survey, 34 lambs:100 ewe-like sheep and 24 rams:100 ewe-like sheep were observed. The results from the 2000 aerial survey were 33 lambs:100 ewe-like sheep and 32 rams:100 ewe-like sheep. During the 2001 aerial survey we observed 17 lambs:100 ewe-like sheep and 30 rams:100 ewe-like sheep. Ratios observed during the 2002 survey were 29 lambs:100 ewe-like sheep and 22 rams:100 ewe-like sheep.

When survey units to the east and west of Anaktuvuk Pass are examined separately, lamb:ewe-like and ram:ewe-like ratios varied considerably and neither area (east or west) had consistently higher lamb:100 ewe-like or ram:100 ewe-like ratios (Table 4). Lamb:ewe-like ratios looked to be poor in both areas in 2001 but lamb:ewe-like ratios reached a high in 1999 in the western units and reached a high in 2000 in the eastern units. Ram:ewe-like ratios varied more than did lamb:ewe-like ratios and in high years were as much as 278% and 219% above the low years in the western units and eastern units, respectively (Table 4).

Table 4. Lamb:ewe-like and ram:ewe-like ratios in survey areas to the west and to the east of Anaktuvuk Pass, Alaska.

Year	Lambs:100 ewe-like	Rams:100 ewe-like
Western Units		
1998	21	22
1999	37	9
2000	27	34
2001	21	14
2002	35	29
Eastern Units		
1998	28	28
1999	32	33
2000	36	31
2001	11	51
2002	25	16

Given the number of sheep observed during 1998 and the 2000-2002 surveys, the low total sheep count during 1999 appears to have been a result of either poor visibility (due to poor weather conditions) or movement of sheep between survey units rather than an actual decline in the sheep population. A large amount of variation in Dall's sheep survey results is not unique to this study (Burch and Lawler 2001; K. Fox, National Park Service, unpublished data; B. Shultz, National Park Service, unpublished data). In 1999, high winds precluded low-level flight in many areas. In addition to affecting the overall count, the possibility exists that certain age and sex classes of sheep were underrepresented during 1999 the survey. Sheep sexually segregate for much of the year and females will often form maternal and nonmaternal bands immediately after lambing (Geist 1971). If one of these classes of sheep tends to utilize more rugged terrain, they would be under represented in the 1999 survey since high winds prevented access to such areas. Conditions were poor enough in 1999 to prevent completion of the survey before the sheep hunting season began for the residents of Anaktuvuk Pass. Disruption of hunting activity was considered unacceptable and as a result, the survey was terminated before all units were surveyed. Although weather conditions were less than optimal in 2000 and 2001, the decisions of where and when to fly particular survey units was done in a more conservative fashion. As a result, fewer survey units were flown but those that were flown were more thoroughly covered than in 1999.

Considerable annual variation existed in survey effort (Table 5). Considering just the four units that were surveyed each year during the five years of this study on the east side of Anaktuvuk Pass, survey effort declined by 43% in 2002 when compared to 2001. Survey effort was 27% less in 1998 when compared to 2002 in the four units that were surveyed every year on the west side of Anaktuvuk Pass. No statistical relationship existed however, between the time it took to survey and the numbers of rams (F= 6.586, *d.f.*= 1,4, P=0.083 east of Anaktuvuk Pass, and F= 0.017, *d.f.*= 1,4, P=0.905 west of Anaktuvuk Pass), ewe-like (F= 1.166, *d.f.*= 1,4, P=0.359 east of Anaktuvuk Pass, and F= 0.000, *d.f.*= 1,4, P=0.996 west of Anaktuvuk Pass), or lambs (F= 0.656, *d.f.*= 1,4, P=0.477 east of Anaktuvuk Pass, and F= 0.504, *d.f.*= 1,4, P=0.529 west of Anaktuvuk Pass) observed during the survey (Fig. 15). Based on this information, differences in numbers and densities of sheep observed during surveys were not attributable to the amount of time spent surveying during the five years of this study.

Table 5. Summary statistics for survey effort of summer aerial Dall's sheep surveys near Anaktuvuk Pass, Alaska.

Survey Year	Area Surveyed (km^2)	Time (h)	km^2 surveyed/ hour	Observed sheep		
				Total	Per km^2	Per h
Western Units						
1998	655	9.45	69.3	83	0.13	8.8
1999	655	10.75	60.9	63	0.10	5.9
2000	316	4.45	71.0	103	0.33	23.1
2001	479	8.03	59.7	154	0.32	19.2
2002	655	10.68	61.3	181	0.28	16.9
Mean	552	8.7	64.4	116.8	0.23	14.8
CV	0.27	0.3	0.08	0.42	0.47	0.49
Eastern Units						
1998	539	9.32	57.8	303	0.56	32.5
1999[a]	471	6.28	75.0	123	0.26	19.6
2000	484	8.25	58.7	357	0.74	43.3
2001	316	4.83	65.4	131	0.41	27.1
2002	539	6.87	78.5	211	0.39	30.7
Mean	470	7.11	67.1	225	0.47	30.6
CV	0.19	0.24	0.14	0.46	0.39	0.28

[a] One unit was not completely surveyed. Sheep seen in this unit are included with the total and with the # of sheep observed per hour but not in the calculation for the number of sheep observed per km^2 surveyed.

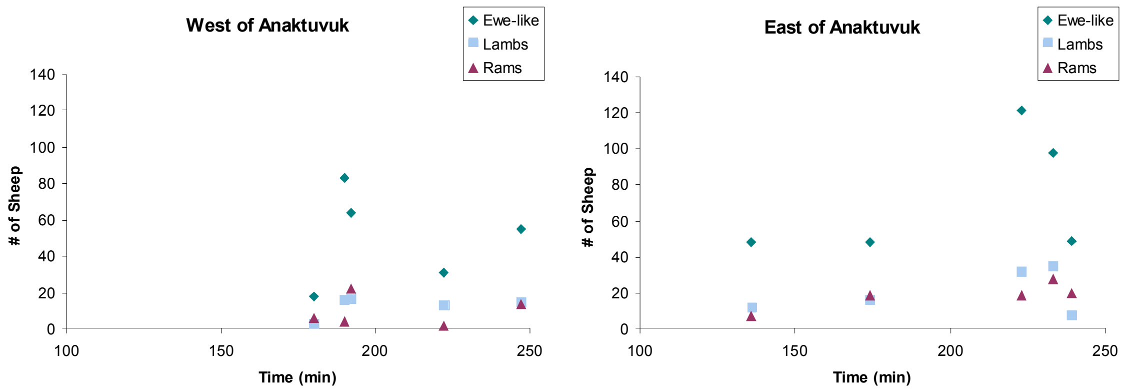

Fig. 15. The relationship between the numbers of sheep observed and the time spent surveying in four survey units to the west and four survey units to the east of Anaktuvuk Pass, Alaska. Aerial surveys were conducted with a small aircraft (Piper Supercub) in July of 1998-2002.

The five year mean (±SE) ram density was over 100% higher in the survey area to the east of Anaktuvuk Pass (0.09 [±0.019] rams per km^2) in comparison to the survey area to the west of Anaktuvuk Pass (0.04 [±0.011] rams per km^2) and this difference was statistically significant (t=3.230, *d.f.* =4, P= 0.03; Fig. 16). Mean (±SE) density of ewe-like sheep was 90% higher to the east of Anaktuvuk Pass (0.29 [±0.047] ewe-like per km^2) in comparison to the survey area to the west of Anaktuvuk Pass (0.15 [±0.032] ewe-like per km^2) and this difference was statistically significant (t=3.295, *d.f.* =4, P= 0.03; Fig. 16). Mean (±SE) lamb density was 93% higher to the east of Anaktuvuk Pass (0.08 [±0.022] lambs per km^2) in comparison to the survey area to the west of Anaktuvuk Pass (0.04 [±0.008] lambs per km^2) but lamb density varied considerably from one year to the next. This variability may be responsible for the lack of statistical significance in lamb density between the two areas (t=1.715, *d.f.* =4, P= 0.161; Fig. 16). This data gives additional credence to the idea of two subpopulations within the study area.

No trend in Dall's sheep populations were identified in the units east of Anaktuvuk Pass(Fig. 16) and this was true for rams ($F_{1,4}$=0.006, P=0.94), ewe-like sheep ($F_{1,4}$=0.005, P=0.95) and lambs ($F_{1,4}$=0.119, P=0.753). West of Anaktuvuk Pass, no statistically significant trend was identified for rams ($F_{1,4}$=1.288, P=0.339) and ewe-like sheep ($F_{1,4}$=3.290, P=0.167) but the increase in lambs observed during the five years of these surveys was significant ($F_{1,4}$=14.695, P=0.031). An examination of the data from the area west of Anaktuvuk Pass (Fig. 16) indicates more rams and ewe-like sheep were observed in the final three years of surveys in comparison to the first two years which suggests an upward trend. With the present data, however, we can not reject the possibility that the population west of Anaktuvuk Pass remained stable from 1998-2002.

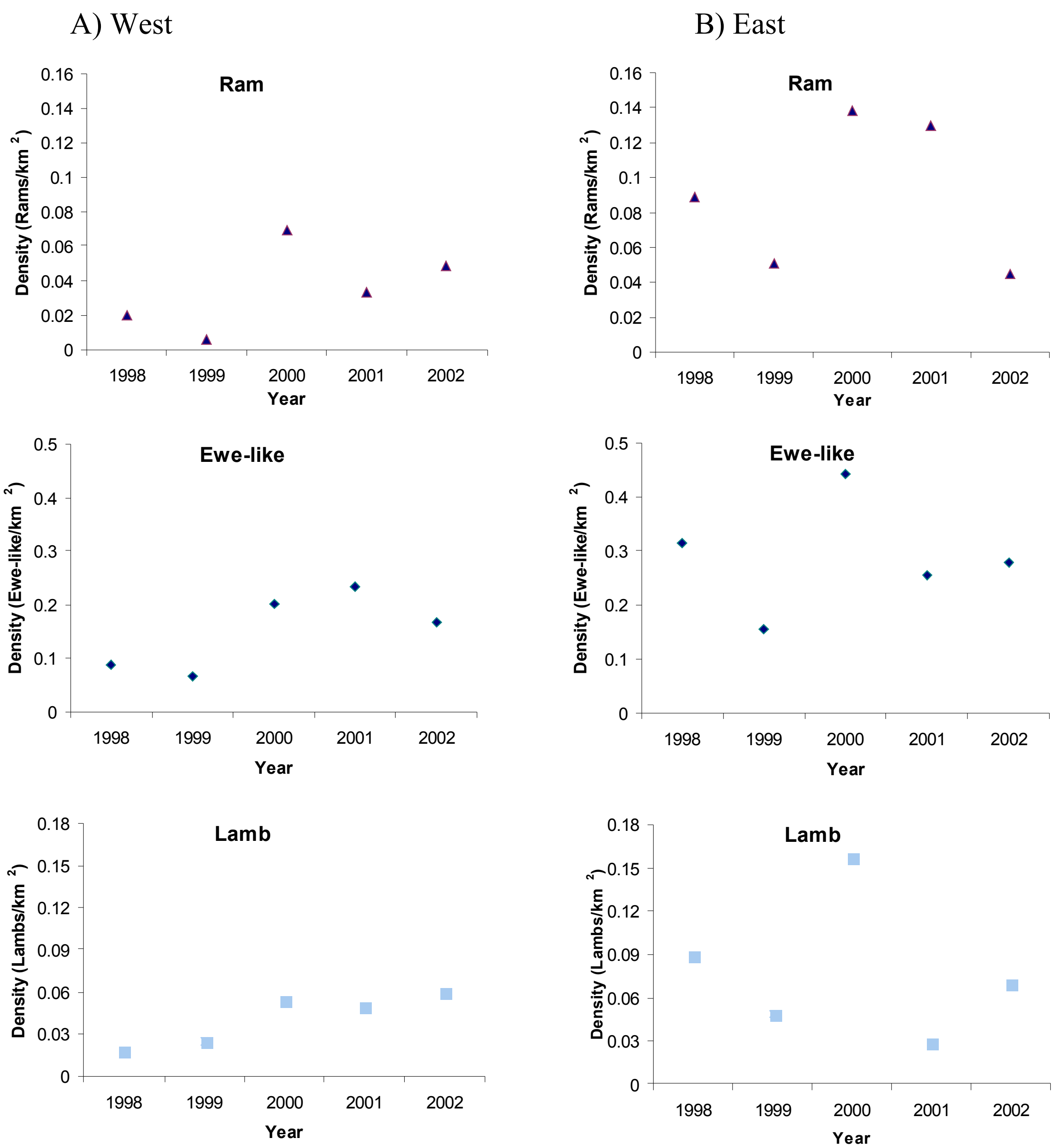

Fig. 16. Population densities of rams, ewe-like sheep and lambs east and west of Anaktuvuk Pass, Alaska based on aerial surveys conducted in early July of 1998-2002.

Two principal problems illustrated by this Dall's sheep aerial survey data are the variation possible in survey results and the statistical problems of small sample sizes (five surveys). Although consistency has been difficult to achieve with these surveys, they should not be abandoned. On the contrary, results from multi-year data sets track population trajectories much better than can occasional surveys. Less reliance is placed on single events and yearly anomalies are buffered. This allows better inferences and understanding of population changes for improved management actions. In addition, lessons learned from these surveys can be applied to future surveys improving results, efficiency and economics. Better results on all surveys can be improved by allocating sufficient time to ensure good weather conditions for the completion of the survey prior to the hunting season. Care must be taken to ensure that survey methods do not vary between years and consistency can be improved by employing the same pilot and observer each year. In addition, surveys should be conduct at the same time each year to eliminate biases introduced by changes in sheep distribution associated with seasonal changes such as lambing and plant phenology. Adherence to these suggestions will improve the comparability of results.

Prior to this study similar sheep surveys, for which we have data, had been conducted in the area surrounding Anaktuvuk Pass during 1974 (Smith 1974), 1982 and 1984 (Singer 1984), 1987 (Adams 1988) and 1996 (Brubaker and Whitten 1998) (Table 6). A small fixed-wing aircraft (Helio Courier) was used to survey portions of the area near Anaktuvuk Pass in 1974. A helicopter was used to count sheep in 1982 and 1984 and the helicopter would occasionally land with the observation crew to determine sex and age classification of observed sheep. In 1982 the survey covered much of Gates of the Arctic National Park and Preserve. In 1984, additional portions of the park were surveyed and some areas surveyed in 1982 were re-surveyed. In 1987, the survey was conducted from a helicopter and the area surveyed was all west of the John River (although more extensive than the 1998-2002 surveys). In 1996, sheep were counted from a Piper Super Cub. Some units in 1996 were recounted with a helicopter to determine sightability of Dall's sheep. Units surveyed in 1996 covered all units surveyed from 1998-2002 but also included additional areas to the east. Although differences in methodology between surveys make direct comparisons of results difficult, examination of previous population estimates is informative (Table 6). All survey results we report in this paper are minimum sheep counts. Only during 1996 was the sightability of sheep determined thereby allowing researchers to adjust the population estimates in the survey area (observed sheep * sightability correction factor = population estimate). During the 1996 survey, sightability was very good resulting in a correction factor of 1.1 (Brubaker and Whitten 1998). This small correction factor is encouraging. It suggests little bias in the fixed-wing counts, that is, under good survey conditions fixed-wing aircraft see almost all sheep in the survey areas. Minimum counts in those years where only fixed-wing aircraft are used can therefore provide a realistic view of sheep population parameters.

Dall's sheep densities have been consistently higher in the survey areas to the east of Anaktuvuk Pass in comparison to those areas to the west (Table 6). Dall's sheep densities were higher in the 1980's than they were in the 90's and early 00's. Mean ($\pm$ 90% Confidence Interval) Dall's sheep observed densities in the five years of 1998-2002 were substantially lower than observed densities in the 80's. Mean ($\pm$90%CI) observed density west of Anaktuvuk Pass from 1998-2002 was 0.23 ($\pm$0.10) sheep per km^2 in comparison to 0.91 sheep per km^2 in 1984 (a 75% reduction). East of Anaktuvuk Pass, mean ($\pm$90%CI) observed density from 1998-2002 was 0.47 ($\pm$0.18) sheep per km^2 in comparison to 0.81 sheep per km^2 in 1982 (a 42% reduction). It is unlikely that the reduction in number of sheep counted is due to differences in search time since more time was typically spent searching a given area in surveys during 1996 and 1998-2002 in comparison to surveys done in the 80's. This evidence suggests that Dall's sheep populations were substantially higher in the area around Anaktuvuk Pass during the mid-80's than they were during this study. The Dall's sheep population in the study area to the east of Anaktuvuk Pass in the mid 70's (0.45 in 1974; Smith 1974) may have been comparable to what was observed during the five years of this study (mean =0.47; Table 6).

Table 6. Observed sheep densities, survey rates and search rates from 1974, 1982, 1984, 1987 and 1996 and mean (± 90% Confidence Interval) sheep densities, survey rates and search rates from 1998-2002 for surveys areas west and east of Anaktuvuk Pass, Alaska.

	Sheep Density ($/km^2$)	km^2 surveyed/h	Observed sheep/h
West of Anaktuvuk Pass			
1974[a]	N/A	N/A	N/A
1982[b]	0.73	93.3	67.9
1984[b]	0.91	N/A	N/A
1987[c]	0.8	71.1	60
1996[d]	0.27	64.7	17.5
East of Anaktuvuk Pass			
1974[a]	0.45	103.2	46.1
1982[b]	0.81	92.4	74.8
1984[b]	N/A	N/A	N/A
1987[c]	N/A	N/A	N/A
1996[d]	0.39	64.7	25.2

N/A. Not available.
Sources: [a] Smith 1974, [b] Singer 1984, [c] Adams 1988, [d] Brubaker and Whitten 1998.

Differences in how data were collected during previous surveys prevents calculation of many of the sex and age statistics typically reported for Dall's sheep populations. Two approximate values that can be calculated from previous surveys are the portion of the population composed of lambs, and the proportion of the population composed of rams with > quarter-curl horns (Table 7).

Substantial variation existed in the number of observed lambs east and west of Anaktuvuk Pass in some years (1996 and 2001; Table 7) but neither area had consistently higher lamb proportions. Likewise, within survey areas, substantial yearly variation existed (Table 7) and ranged from a relatively high proportion of lambs (36% in 1996 west of Anaktuvuk Pass) to quite low (7% in 2002 east of Anaktuvuk Pass). Although the highs and lows for the proportion of lambs in the observed populations east and west of Anaktuvuk Pass tended to track one another, enough variation existed in these peaks and troughs to suggest that the populations east and west of Anaktuvuk Pass were behaving differently, perhaps responding to small scale variations in weather conditions.

Table 7. Proportion of observed sheep composed of lambs and rams > quarter-curl from 1982, 1984, 1987, 1996 and 1998-2002 for a survey area west and east of Anaktuvuk Pass, Alaska.

	Proportion of lambs	Proportion of rams (>1/4 curl)
West of Anaktuvuk Pass		
1982 [b]	0.18	0.12
1984 [b]	0.22	0.15
1987 [c]	0.21	0.16
1996 [d]	0.36	N/A
1998 [e]	0.14	0.16
1999 [e]	0.25	0.06
2000 [e]	0.17	0.21
2001 [e]	0.15	0.11
2002 [e]	0.22	0.18
East of Anaktuvuk Pass		
1982 [b]	0.20	0.16
1984 [b]	N/A	N/A
1987 [c]	N/A	N/A
1996 [d]	0.26	N/A
1998 [e]	0.16	0.16
1999 [e]	0.19	0.20
2000 [e]	0.21	0.19
2001 [e]	0.07	0.31
2002 [e]	0.18	0.11

N/A. Not available.
Sources: [a] Smith 1974, [b] Singer 1984, [c] Adams 1988, [d] Brubaker and Whitten 1998, [e] present study.

The percentage of observed rams with > quarter-curl horns also showed considerable variation. Neither of the two study areas tended to have more rams than the other (Table 7). In some years the proportion of rams observed in the two study sites was equivalent (1998; Table 7) and in other years quite different (2001). Unlike the lamb data, there was no indication that ram percentages tracked each other between the two study areas. Changes in the number of rams observed from year to year are biologically unrealistic. Two possibilities exist for these large shifts in percentage of observed rams. One possibility is that segments of the Dall's sheep population in the area around Anaktuvuk Pass move in and out of survey units from year to year. Evidence presented in this report from radiocollared sheep refutes this. In other areas of the state however, considerable variation exists in yearly Dall's sheep distribution (Burch and Lawler 2001, Kleckner et al. 2002). A second possibility is that sex and age classes of sheep vary in sightability. This possibility is plausible and is supported by observations that groups composed primarily of ewe-like sheep and lambs tend to be larger in the summer than ram groups and would likely be more apparent during surveys. Low proportions of rams were observed during two of the years when conditions were marginal (1999 and 2001). These results emphasize the need to only conduct surveys when conditions are optimal for flying and sightability.

Dall's sheep populations across the Brooks Range have followed a similar trend to the sheep around Anaktuvuk Pass. Mauer (US Fish and Wildlife Service) found that sheep in the eastern Brooks Range in the Hulahula drainage of the Arctic National Wildlife Refuge increased from 1976-1986 and then declined by more that 50% by 1993 (cited by Brubaker and Whitten 1998). Evidence from Singer (1984) indicated a 13% increase in Dall's sheep populations across large portions of Gates of the Arctic National Park and Preserve from 1982-1984 and higher sheep populations in the 80's than in the 70's. Singers data included the survey areas around Anatuvuk Pass but encompass a much larger area (Singer 1984) including surveys done in other locations in Gates of the Arctic National Park and Preserve (Grauvogel 1974, Smith 1974). Adams in 1987 found 27% more sheep than did Singer in 1982 in a survey area that included the units around Anaktuvuk Pass as well as a larger portion of the Central Brooks Range. To the west, population estimates of Dall's sheep in the Baird Mountains climbed by 45% between 1986 and 1989 before dropping more than 52% in 1991 (Brad Shults, National Park Service, unpublished data). The Baird population appears to be slowly recovering (B. Shults, pers. comm.). The decline in sheep populations during the late 1980's across the Brooks Range suggests a wide spread phenomena. Large scale weather patterns across northern Alaska have been suggested as a probable culprit (Whitten 1997).

Ground Surveys

Gates of the Arctic National Park and Preserve is both a park in which hunting is permitted and a wilderness area. Monitoring of wildlife populations is necessary in order to fulfill park mandates and to ensure stability of wildlife populations within this area. Aerial surveys, although effective and efficient, may conflict with Park visitors perception of wilderness and wilderness values. This potential conflict led to the goal of developing ground based survey methods within Gates of the Arctic National Park and Preserve. Conceptually, in addition to reducing impacts on visitor experiences within the Park and Preserve, ground based surveys would allow greater discrimination in sexing and aging sheep. We attempted to achieve this goal using three methods. During the 1998 field season, a known mineral lick near Anaktuvuk Pass, Alaska was monitored for sheep. In 1999, three routes through known sheep habitat were hiked and sheep were counted and classified along the way. In 2000, the John River was floated and sheep were surveyed during day hikes into selected areas.

Methods

From 27-30 June, 1998, a mineral lick along the John River, within the aerial survey study area, was accessed by foot. Groups of sheep had been observed in the area during radiotracking flights and during the concurrent aerial survey. Composition counts were conducted using a Questar telescope, so that ewes could be differentiated from yearlings and young rams, and more accurate lamb:yearling:ram:ewe ratios could be estimated. Ground surveyors were Denny DiFolco, Donna DiFolco, Elvin Dayton, and Rachel Brubaker.

Immediately following the 1999 aerial survey, three teams of observers hiked routes near Anaktuvuk Pass through known sheep habitat. Two routes were chosen to go through the aerial survey units to the west of Anaktuvuk Pass and one route was selected to go to the east of Anaktuvuk Pass (Fig. 17). Routes were hiked beginning on the afternoon of 14 July and concluded on the afternoon of 19 July. Sheep encountered along these routes were enumerated and classified by sex and age. Observers during this survey were John Burch, Josh Ernst, Jim Lawler, Chris McKee, Jessie Reakoff, and Todd Rinaldi.

The John River was floated from 3-7 July 2000 from Anaktuvuk Pass to Hunt Fork Lake. Hikes were taken on two days in known sheep habitat during the trip and potential sheep habitat was scanned while floating (Fig. 17). One of the day hikes occurred in the Kollutuk drainage on 4 July and the other occurred on Publituk on 6 July. Sheep encountered were classified by sex and age. Observers on this survey were John Burch and Jim Lawler.

Results and Discussion

A total of five sheep (3 ewes, 1 half-curl ram, 1 lamb) were observed by ground crews during the 1998 mineral lick survey. Groups of sheep observed from the air could not be accessed by foot before the sheep moved to other areas. This small sample size does not allow for any conclusions regarding population structure during 1998.

During the 1999 survey, a total of 50 sheep were observed along the 79 km (49 miles) of terrain covered by the three survey crews. The total included 28 adult ewes, 10 lambs, 6 yearling and 6 rams. Observed rams included 3 quarter-curl rams, 1 half-curl ram, 1 seven eights-curl ram, and 1 full curl ram. Ratios of adult ewes to other age and sexes classes were as follows: 36

lambs:100 ewes, 21 yearlings:100 ewes, and 21 rams:100 ewes.

The 1999 foot survey encountered difficulties with weather beginning on the evening of 15 July with heavy rain and fog. By the evening of 16 July, rain had turned to snow and fog persisted. The evening of 17 July saw 3-4 inches of snow covering the ground at high elevations and intermittent periods of dense fog. By 18 July, partial clearing had occurred but snow persisted at high elevations. Therefore, because of the weather, sightability of sheep was extremely poor. In addition, hiking routes did not cover the amount or type of terrain anticipated to adequately sample the sheep populations due to treacherous hiking conditions at the higher elevations.

Weather varied during the 2000 survey from relatively good to rainy, foggy and windy. Seventy-four sheep were observed during the 2000 survey. Sixty km (38 miles) of terrain were covered by floating and 32 km (20 miles) of terrain were covered by hiking. Traveling conditions were good throughout the survey both for foot travel and for floating. Sex and age distribution of sheep observed were 44 ewes, 18 lambs, 4 yearlings, 3 half-curl rams, 1 three quarter-curl ram, 1 seven eights-curl ram, and 3 full-curl rams. Ratios of adult ewes to other sex and age classes were 41 lambs:100 ewes, 9 yearlings:100 ewes, and 18 rams:100 ewes.

Ground-based surveys are attractive because they can provide accurate sex and age classification data. However in low-density sheep areas, it is difficult to get sufficient sample sizes to provide meaningful population structure information. Entire groups of sheep can be missed and this can be particularly problematic where sheep are segregating by sex, age or presence of lambs. Additional disadvantages of ground-based surveys include a high labor and time cost. Ground surveys have not been successful in Gates of the Arctic National Park and Preserve due to low sheep densities, poor access and poor weather. If ground surveys are to continue, the most promising method would be a combination of hiking and a John River float/hiking trip. Adding additional hiking routes and people to cover these routes would have the dual benefit of increasing sample size as well as increasing the likelihood that all sex and age classes of sheep are appropriately sampled during the survey. Given good weather and sheep location information from the aerial survey, this method has the potential of being successful as a means to estimate lamb:ewe and ram:ewe ratios. Regardless of methods used, effort should concentrate in areas of highest known sheep density. Given this criteria, Publituk and Publituk Creek would be good candidates for inclusion in future survey efforts. Results from this survey would be most useful in evaluating the relative success of lambing since anecdotal observations indicate this area is predominately used by lamb:ewe groups.

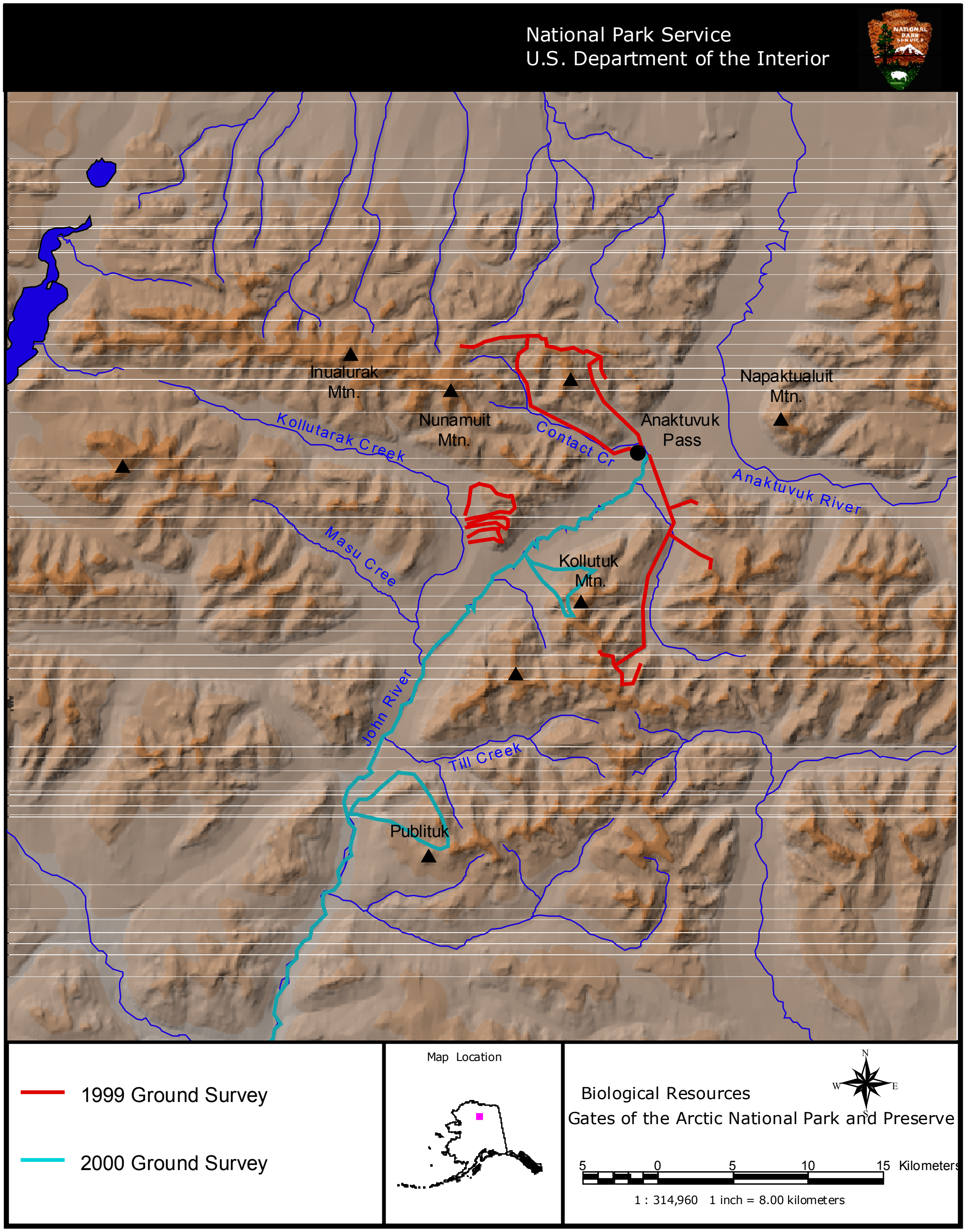

Fig. 17. Locations of ground surveys used to count, sex and age Dall's sheep during July 1999 and 2000 near Anaktuvuk Pass, Alaska.

IV. Dall's Sheep Harvest by Subsistence Users, Anaktuvuk Pass, Alaska

Regulations regarding the subsistence harvest of Dall's sheep by the residents of Anaktuvuk Pass, Alaska were altered in 1997. Spring hunting of Dall's sheep was eliminated to more accurately reflect subsistence harvest patterns by the community of Anaktuvuk Pass. Current regulations allow residents of Anaktuvuk Pass to hunt Dall's sheep from July 15 – Dec. 31. Harvest regulations changed from a personal bag limit of 3 sheep per person to a community harvest quota of 60 sheep, no more than 10 of which may be ewes and a daily possession limit of 3 sheep per person, no more than 1 of which may be a ewe. To ensure these limits were not exceeded, a voluntary reporting process was initiated by the National Park Service beginning in July 1997.

Methods

Residents of Anaktuvuk Pass voluntarily report their harvest to the Anaktuvuk Pass Ranger of Gates of the Arctic National Park and Preserve residing in the community. Information collected includes the number, sex and age class of sheep harvested, dates harvested and a general location and condition of the sheep.

Results and Discussion

A summary of sheep harvested from 1997 to 2002 is provided in Table 5. During the 1998 season, harvest occurred in July (*n*=1), August (*n*=5), September (*n*=9) and October (*n*=1). In 1999, harvest occurred in July (*n*=7), August (*n*=5),), October (*n*=1) and November (*n*=4). During 2000, sheep harvest occurred in July (*n*=3), September (*n*=3), October (*n*=5) and November (*n*=1). The 2001 harvest was primarily in October (*n*=3) with 1 sheep taken in September and 1 in August. In 2002 sheep were harvested in July (*n*=5) and August (*n*=3). Based on these statistics, harvest over the five years of this study was relatively constant from July-November and than tapered off in December. Harvest that occurred within the study area was almost equally split between the western survey units (54%; *n*=29) and the eastern survey units (46%, *n*=25).

The 57 Dall's sheep that were recorded as harvested during the five years of this study (1998-2002), were harvested by 23 individuals. We have no record of any individual harvesting sheep every year during this study but some individuals contributed to the harvest more than others. Three individuals harvested 30% of all sheep harvested from 1998-2002. Anaktuvuk Pass Dall's sheep harvest was primarily rams (67%) during the five years of this study (Table 7). No information was collected on age classes of rams harvested but this would be valuable information to be collected in future efforts. Assuming a conservative yearly population of approximately 340 animals (5 year mean of observed animals), yearly harvest by Anaktuvuk Pass subsistence users has ranged between 5% and 1% of the population.

Table 8. Dall's sheep harvest for the community of Anaktuvuk Pass, Alaska. Records have been maintained since the initiation of a community harvest quota of 60 Dall's sheep.

Harvest Year	**Number of Sheep Harvested**			
	rams	**ewes**	**lambs**	Total
1997	10	1		11
1998	10	6		16
1999	13	4		17
2000	4	7	1	12
2001	3	2		5
2002	6	2		8
Totals:	46	22	1	69

Estimates of yearly sheep harvest for the community of Anaktuvuk Pass in previous years were 38 sheep in the first subsistence hunt in 1982-1983 and similar harvests in the next two years (Singer 1984). Reported sheep harvest in 1989-1990 was 27, in 1990-1991 it was 22 sheep, in 1991-1992 it was 23 sheep, in 1992-1993 it was 22 sheep, in 1993-1994 it was 15 sheep, in 1994-1995 it was 26 sheep, and in 1995-1996 it was 10 sheep (Osborne 1996). Based on these estimates, Dall's sheep harvest by the community of Anaktuvuk Pass from 1998-2002 may be under reported. A second alternative is that fewer people are hunting Dall's sheep. This alternative is supported by the general downward trend in sheep harvest reported. Clarifying if this decline is a lack of reporting or a decrease in harvest is important. No assessment of the impacts of hunting on this population is possible without this information. A more formal process for gathering data may be needed to ensure this data is collected in the future.

V. Management Implications

- Gates of the Arctic National Park and Preserve contains a large number of Dall's sheep (potentially 10% of total world population). They are mentioned in the enabling legislation for the Park and epitomize the mountainous nature of the area. Sheep are non-migratory and management of their populations within GAAR are therefore of particular importance.
- Blood samples and throat swabs do not indicate any abnormal disease conditions in this population of sheep. Mortality rates and patterns are comparable to other stable populations of sheep.
- Radiotracking data indicate sheep show high fidelity to home ranges and the size of home ranges are relatively small. Sub-populations of sheep in specific areas therefore may be vulnerable to extirpation and this needs to be considered when evaluating potential impacts of hunting. It is not known is how quickly sheep will re-colonize suitable areas.
- Dall's sheep populations across the Brooks Range crashed in the late 1980's. Evidence from survey areas near Anaktuvuk Pass suggests that population recovery is slow. Management of Dall's sheep hunting in the area around Anaktuvuk should therefore be conservative if Park Management wants Dall's sheep populations to recover to the levels observed in the mid-1980's.

- Dall's sheep populations in the Brooks Range can exhibit large scale population fluctuations. Baseline data is necessary to determine the specifics of these fluctuations and to adjust management accordingly. Better data is needed on Dall's sheep ecology and habitat quality across the Brooks Range to assign cause and effect relationships.
- Results from population estimates of sheep appear to vary in quality. This variation emphasizes the need to repeatedly survey in a consistent fashion. Only in this way can we hope to detect real changes in the sheep population. Future surveys should allocate enough time and personnel to ensure that the survey can be done in good conditions. Surveys conducted from 1998 – 2002 allocated a short time just prior to the opening of the subsistence sheep season to count sheep. This left little time to adjust survey timing to match environmental conditions, particularly since we restricted the survey to before the start of the hunt. In addition, future surveys should target a specific times of the year. This may reduce variability introduced by seasonal differences in distribution of sheep.
- Ground surveys, although attractive, have had little success in GAAR. This may be due to a combination of poor luck and inadequate investment of time and personnel. These techniques have been used with success in other locations where the primary purpose has been to evaluate lamb production and overwinter recruitment of lambs (i.e., yearlings). It is difficult to estimate population sizes and densities based on ground surveys, particularly in large areas of continuous sheep habitat. Consequently population level inferences based on ground surveys are limited.
- The level of subsistence harvest on Dall's sheep in the area surrounding Anaktuvuk Pass is unlikely to be detrimental to the sheep population. However, based on previous reported harvest, current levels of harvest have declined or sheep harvest is being under reported. Effort should be directed to find out if sheep harvest is under reported and more effort should be directed at gathering information from the harvest. For example, age composition of harvested sheep and would be easy and informative data to gather. In addition, more specific information regarding locations of harvest would be helpful in evaluating the effects of sheep harvest.

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APPENDIX 1. Summary of June / July Dall's sheep surveys near Anaktuvuk Pass in Gates of the Arctic National Park and Preserve, Alaska 1996-2002. Sheep surveys in 1996 were flown with helicopters and surveys done in 1998-2002 were done with fixed-wing aircraft.

2002

UNIT No.	area mi^2	ewe-like	rams	lambs	TOTAL	Survey Time (min)
54	21.3	12	1	2	15	50
55	19.8	17	2	5	24	52
56	27.7	28	3	6	37	63
57	28.0	7	1		8	42
58	20.9				0	19
59	27.8	41	6	12	59	51
60	25.7	22	6	6	34	42
61	30.8	23	5	6	34	69
62	19.8				0	24
76	20.7		10		10	49
77	15.3				0	42
78	20.7				0	53
79	31.9	8		4	12	67
81	24.3	6	3		9	28
82	16.6	6		2	8	46
83	27.8	49	4	13	66	97
85	20.8				0	55
86	21.6	5		3	8	78
87	26.8		1		1	48
88	26.7	36	14	17	67	78
TOTAL*						
	475.3	260	56	76	392	1053

* Total area surveyed in 2002.

2001

UNIT No.	area mi^2	ewe-like	rams	lambs	TOTAL	Survey Time (min)
54	21.3					
55	19.8					
56	27.7					
57	28.0				0	27.98
58	20.9		3		3	20.94
59	27.8	49	17	8	74	27.81
60	25.7	32	21	1	54	25.73
61	30.8					
62	19.8				0	19.83
76	20.7		1		1	20.74
77	15.3					
78	20.7					
79	31.9					
81	24.3	3	6		9	24.34
82	16.6	6	2		8	16.59
83	27.8	44		10	54	27.82
85	20.8	33	1	6	40	20.8
86	21.6	17		3	20	21.63
87	26.8		6		6	26.83
88	26.7	9		4	16	26.72
TOTAL*						
	307.8	193	57	32	285	307.76

* Total area surveyed in 2001.

2000

UNIT No.	area mi^2	ewe-like	rams	lambs	TOTAL	Survey Time (min)
54	21.3					
55	19.8	21	16	10	47	55
56	27.7	37	2	13	52	54
57	28.0				0	31
58	20.9	42	3	12	57	56
59	27.8	56	25	23	104	102
60	25.7	30	9	10	49	72
61	30.8	28	12	8	48	81
62	19.8				0	44
76	20.7		6		6	45
77	15.3				0	35
78	20.7				0	40
79	31.9					
81	24.3					
82	16.6	11		7	18	40
83	27.8	53	8	10	71	52
85	20.8		8		8	55
86	21.6					
87	26.8					
88	26.7					
TOTAL*						
	322.6	278	89	93	460	762

* Total area surveyed in 2000.

1999

UNIT No.	area mi^2	ewe-like	rams	lambs	TOTAL	Survey Time (min)
54	21.3				0	47
55	19.8	6	4		10	52
56	27.7	18		7	25	35
57	28.0	6[a]	7[a]	1[a]		
58	20.9	30	1	10	41	57
59	27.8	9	11	3	23	42
60	25.7					
61	30.8	1	1		2	69
62	19.8	3		2	5	48
76	20.7		2		2	51
77	15.3	4		2	6	51
78	20.7		1		1	40
79	31.9	5		1	6	66
81	24.3	1			1	59
82	16.6				0	49
83	27.8	11		6	17	68
85	20.8	20		7	27	54
86	21.6	2	1		3	70
87	26.8				0	77
88	26.7				0	60
TOTAL*						
	421.54	110	21	38	169	995

* Total area surveyed in 1999.
[a] These values were not included in the total count because the survey of this unit was aborted midway through. The values were used however, in calculations of ewe-like:lamb and ewe-like:ram ratios.

1998

UNIT No.	area mi²	ewe-like	rams	lambs	TOTAL	Survey Time (min)
54	21.3				0	52
55	19.8	5	8	4	17	69
56	27.7	48		9	57	75
57	28.0	8		1	9	60
58[a]	20.9	47		13	60	44
59	27.8	66	19	18	103	72
60	25.7	15	8	2	25	68
61	30.8	12	13	7	32	72
62	19.8				0	47
76	20.7	2	6		8	47
77	15.3	11	3		14	45
78	20.7	5	2	3	10	47
79	31.9	21	1	5	27	77
81	24.3				0	30
82	16.6				0	37
83	27.8				0	38
85	20.8	16		3	19	58
86	21.6	3	1	1	5	60
87	26.8				0	64
88	26.7				0	64
TOTAL*						
	475.3	259	61	66	386	1126

* Total area surveyed in 1998.

[a] One group of 31 adult sheep were unclassified during the survey. These animals were categorized as "ewe-like" in this appendices on the basis of 6 lambs associated with the group. None of the animals associated with this group (31 adults and 6 lambs) were used to calculate ewe-like:lamb or ewe-like:ram ratios.

1996+

UNIT No.	area mi^2	adults	lambs	TOTAL	Survey Time (min)
54	21.3	2	1	3	39
55	19.8	11	3	14	72
56	27.7	16	9	25	45
57	28.0	32	8	40	34
58	20.9	19	9	28	30
59	27.8	8	1	9	45
60	25.7	76	21	97	83
61	30.8	18		18	72
62	19.8	6	2	8	40
76	20.7	15	1	16	42
77	15.3	29	14	43	50
78	20.7	13	3	16	37
79	31.9	29	11	40	66
81	24.3	0		0	28
82	16.6	8	4	12	39
83	27.8	15	6	21	60
85	20.8	19	12	31	54
86	21.6	20	3	23	64
87	26.8	0		0	36
88	26.7	1		1	72
TOTAL*					
	475.3	337	108	445	1008

+ Survey conducted with a helicopter and not a fixed-wing aircraft.
* Total area surveyed in 1996.