Jim Hayvell

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THE REACTION OF SOME MAMMALS TO AIRCRAFT AND COMPRESSOR STATION NOISE DISTURBANCE

Edited by

R. D. JAKIMCHUK

Prepared by

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The Arctic Gas Biological Report Series, of which this volume is a part, is a series of consultant project reports presenting data based on field and laboratory studies. The format and presentation varies among reports in accordance with the authors' discretion.

The data for this work were obtained as a result of investigations carried out by Renewable Resources Consulting Services Ltd. for Alaskan Arctic Gas Study Company and Canadian Arctic Gas Study Limited. The text of this report may be quoted provided the usual credits are given.

CHAPTER II

THE EFFECTS OF SIMULATED COMPRESSOR STATION SOUNDS ON DALL SHEEP USING MINERAL LICKS ON THE BROOKS RANGE, ALASKA

PATRICIA C. REYNOLDS

ABSTRACT

The effects of simulated sounds of a 20,000-horsepower gas compressor station on Dall sheep at mineral licks were studied. Observations were made during two control phases (simulator off) and one experimental phase (simulator on) at each of two licks, one of which was subjected to 58-73 decibels of sound and the other to levels too low to be recorded. No statistically significant difference was determined in numbers of sheep, sheep-hours, average time spent, and sexual composition at the licks between the control and experimental phases. Sheep spent less time in those parts of the licks which received the highest sound levels. The response of sheep to a sudden turning on of the simulator was tested. Reaction of sheep at the licks to aircraft is described. The responses of several other species to simulator sound are also described.

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TABLE OF CONTENTS

LIST OF TABLES

PAGE

PAGE

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Alignment sheets of the interior alternative proposed gas pipeline along the Marsh Fork of the Canning River indicate that a compressor station may be located adjacent to mineral licks used extensively by Dall sheep. The noise generated by the turbines and flowing gas could disturb sheep using these licks. The experiments described below were designed to determine the impact of the noise on Dall sheep.

Mineral licks appear to be important in determining distribution and movement of sheep (Pitzman, 1970; Heimer and Smith, 1972). They may provide minerals or trace elements needed by ungulates during certain times of the year (Cowan and Brink, 1949; Knight and Mudge, 1967). If the use of licks is physiologically important to animals, as suggested by Hebert and Cowan (1970), disturbance at mineral licks could have a detrimental effect on the population if it resulted in abandonment of the licks and alternatives were not available.

Other studies suggest that sheep may be sensitive to disturbance. During an experiment in Canada, Dall sheep left the area when subjected to the simulated sounds of a compressor station (McCourt *et al.*, 1974). Linderman (1972) suggested that intensive human activity could have caused sheep to abandon part of their summer range. Geist (1971) found that disturbance by hunters may have resulted in sheep deserting their traditional home ranges.

In order to test the effects of auditory disturbance on Dall sheep using mineral licks, an experiment was designed in which sheep were subjected to the simulated sounds of a compressor station. The objectives of the experiment were:

1. To compare numbers and activity of sheep between control and experimental conditions at two mineral licks located different distances from the sound source.

2. To determine if all segments of the population (rams, ewes, and lambs) utilized the licks during control and experimental conditions.

3. To compare numbers and location of sheep in the vicinity of the licks between control and experimental conditions.

4. To evaluate the magnitude of auditory disturbances to which the sheep were exposed prior to and during the experiment.

5. To assess the effects of simulated compressor station sounds on other species in the area.

6. To make recommendations concerning sound attentuation and compressor station locations.

METHODS

Study Area

The study area was located on the Marsh Fork of the Canning River at 69°03'N and 146°04'W, approximately 15 miles upstream from the confluence of the Marsh Fork and Canning rivers. The area was selected because it contained major mineral licks which were adjacent to a proposed compressor station site. Also, sheep were abundant in the area during June and July. Three days of intensive observation prior to the onset of the simulator experiment indicated that sheep were still using the mineral licks in late July.

The study area lay within a river valley bounded by mountains. The two mineral licks observed during the study were found on opposite sides of the river (Plate 1). One lick, designated as L-4, was located on the east side of the river at the base of a 400-foot gravel bank (Plate 2). Mineral lick L-4 contained at least three distinct licking areas, outcrops of chalky soil at which sheep spent most of their time.

The mineral lick on the west side of the river was designated as L-18 (Plate 3). It was located approximately 1 mile southwest of L-4 in a grey gravel bank which bordered a tributary creek of the Marsh Fork. Specific licking areas were not distinctive at mineral lick L-18. The bank, rising 140 feet above the creek, had been eroded into several shallow gullies in which most of the licking occurred.

A third mineral lick, located approximately 2 miles north of L-4 on the west side of the river, was not included in the study.

Mineral licks L-4 and L-18 were probably used by different subpopulations of sheep. Animals came into L-4 on trails which crossed the plateaus and hills east of the lick. Sheep using L-18 came from the mountain slopes to the north and west.

Observations of the two licks and adjacent summering areas were made from a camp situated on a flat bench west of the river, approximately 1/4 mile north of L-18 and 3/4 mile southwest of L-4 (Plate 1). The camp was visible to sheep utilizing L-4 but was partially concealed from sheep at L-18 by a thick patch of willows.

Experimental Apparatus

A sound simulator designed and constructed by J-Mar Electronics of Toronto, Ontario was used to reproduce the sounds of a turbine-powered gas compressor station (Plate 4). Four main sounds were simulated: the exhaust, which consists of high and low frequency components, the gas scrubber, the

PLATE 1: Simulator experiment study area.
C camp and observation area
S simulator
P proposed compressor station site
—— mineral lick

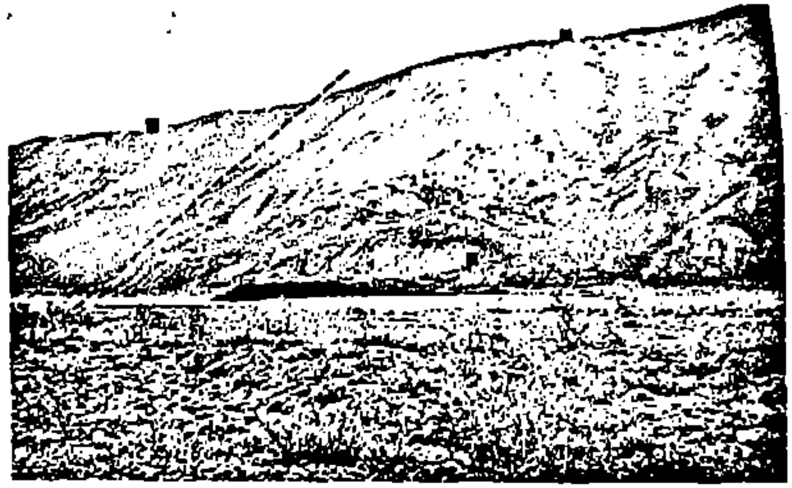

PLATE 2: North and mid-licking areas at mineral lick L-4.
N north lick
M mid-lick
■ locations where acoustical measurements were made.

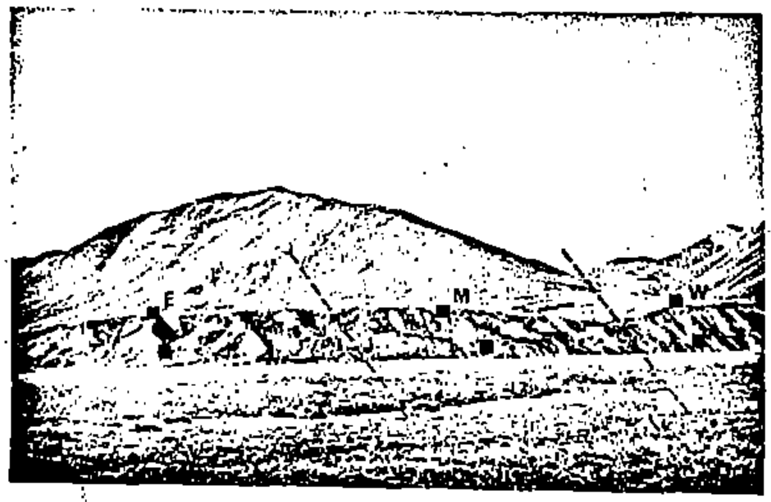

PLATE 3: Mineral lick L-18.
E east lick
M mid-lick
W west lick
■ locations where acoustical measurements were made.

PLATE 4: Sound simulator.

air intake, and the refrigerator bypass. These sounds, synthesized by various filters placed in noise generators, reproduce the basic frequencies present in the actual sounds of a 20,000 horsepower turbine driven gas compressor.

A series of loud speakers set at different heights and directions reproduces the original polar pattern of sounds being emitted from a compressor. A detailed description of the design of the apparatus is available from the manufacturers.

The simulator consists of two identical units set 50 feet apart. During this experiment only one unit was functioning. Investigators conducting similar studies in Canada felt that the total sound output was not appreciably reduced when only one unit was used (McCourt, Feist, Doll and Russell, 1974).

Sound level measurements of various simulator components are compared in Table 1 with similar measurements made by the above authors and J-Mar Electronics (unpublished instruction manual, J-Mar Electronics Limited, Toronto, Ontario). All measurements were taken 15 feet in front of the sound source using a decibel meter set for the "C" weighting network. The needle speed was at "slow" for J-Mar and Marsh Fork measurements.

J-Mar measurements are control values made by the

Table 1. Sound pressure level readings of simulator component sounds measured 15 feet from the simulator by three different investigators.

Component	Source of the Measurement		
	J-mar Electronics Control Values	Renewable Resources Simulator Study	Marsh Fork Simulator Study
Air Intake	96 dB	88 dB	82.5 dB
Scrubber	95 dB	95 dB	105.0 dB
Bypass	86 dB	102 dB	107.5 dB
Exhaust LF	100 dB	97 dB	90.5 dB
Exhaust HF	-	78 dB	80.5 dB
All Components	-	107.5 dB	110.5 dB

manufacturers of the apparatus. Under practical conditions, measurements may vary as much as 10 decibels from these designed values. The measurements herein reported and those by McCourt et al. (1974) were generally within this expected variation when compared with each other, but often differed from J-Mar control values. This variation could be due to differences in terrain, temperature, wind, extraneous noises, etc., or the apparatus may not have been functioning as precisely as it should. Total sound levels were probably not reduced, however, as sounds louder than control values were of an equal or greater occurrence than sounds softer than control values. Differences in sound quality are not known.

The simulator was designed to reproduce sounds of a 20,000 horsepower compressor station, although the unit proposed for the Marsh Fork may be a 30,000 horsepower station with gas chilling. Sound pressure levels which would be produced by such a station have been calculated (Ray Glasrud, Northern Engineering Services Company Limited, pers. comm.) and are compared with sound pressure level measurements made of simulator sounds at similar distances in Table 2.

All measurements and calculations were based on decibel meter readings using the "C" weighting network. Distances recorded for compressor station calculations include a range of 200 feet as various units within the station will be at

Table 2. A comparison of sound pressure levels measured from the simulator and calculated for a 30,000 horsepower compressor station.

Source of the Calculation or Measurement	Distance from Sound in Feet	Sound Pressure Level in Decibels
Sound simulator	300	78-92*
Compressor station	300 - 500	80.4
Sound simulator	600	61-90*
Compressor station	600 - 800	73.1
Sound simulator	1320	53 - 82*
Compressor station	1300 - 1500	66.0

*Based on measurements made by Renewable Resources (1973) at three locations.

least that far apart. Compressor station sound calculations are maximum levels for a given distance. Simulator sound pressure levels are based on measurements made by Renewable Resources Consulting Services Ltd. (1973) at Old Crow, Jago River and Schaeffer Mountain. Their wide range reflects differences in acoustical conditions at each location.

The comparisons indicate that the simulator produces a level of sound similar in magnitude to sound levels theoretically emitted from a 30,000 horsepower compressor station. Differences in sound quality are not known as adequate comparisons of frequencies could not be made.

The sound simulator was set up on the wide bench west of the river directly opposite the middle portion of mineral lick L-4 and approximately 1/4 mile away. It was located approximately 3/4 mile north of mineral lick L-18 within 500 yards of the proposed compressor station site (Plate 1). The sound was directed at L-4.

The Experiment

Design

The simulator experiment consisted of three phases. Phase I was a control phase with the simulator absent from the study area. Observations were made at both licks from

1330 on 16 July to 1300 on 21 July, for a total of 106.0 hours, in order to determine "normal" sheep activity at these mineral licks. Phase II was an experimental phase. The simulator was transported to the study area by helicopter and was turned on about midnight, when no sheep were in the licks or in the vicinity of the licks. Observations were made from 0300 on 23 July to 2100 on 27 July, for a total of 108.0 hours, in order to observe the effects of simulator sounds on sheep using the mineral licks. Phase III was another control phase following the experimental phase. The simulator was turned off but not removed. Observations on sheep using the licks were recorded from 0500 on 2 August to 2000 on 5 August, for a total of 66.5 hours.

Data Collection

Sheep Data

The two licks and the surrounding vicinity were observed with binoculars and a spotting scope. Data on sheep numbers and activity were recorded every 30 minutes. Twenty-four hour observation periods were maintained for a total of five days during Phases I and II. During the rest of the study, 16 to 21 hours of observation were made each day. During these days, observations began from 0300 to 0530 and ended from 2000 to 2400.

The number of sheep that were resting (lying down) and active (engaged in any other activity) at each lick was recorded on data sheets during each 30-minute time period. Behavioral observations such as panic flights were noted. During experimental Phase II and control Phase III, the specific location of sheep and their movements into and out of the licks were also recorded. To facilitate this data collection, the licks were divided into recognizable units. At mineral lick L-4, the three major licking areas formed natural divisions into a north lick, mid-lick and south lick. Portions of the north and mid licks are shown in Plate 2. Mineral lick L-18 appeared to be more continuous but it was arbitrarily divided into a west lick, mid-lick and east lick (Plate 3).

When individuals at a lick could be seen well enough, they were classified as rams, "ewes" and lambs. Rams were adult males larger than 1/4 curl. "Ewes" included adult females and yearlings as well as young rams smaller than 1/4 curl which are difficult to distinguish from ewes (Geist, 1971). Lambs were juveniles born a few months earlier, easily identified by their size.

Numbers of resting and active sheep observed in the vicinity of the licks were also recorded every 30 minutes. Their location was noted as a grid coordinate determined from a grid map of the study area.

Other Data

In addition to sheep activity, data on weather, aircraft activity and other species were also collected. Air temperature, (°F), percent cloud cover, estimated wind speed (light = 1-5 mph; moderate = 5-10 mph; and strong = >10 mph), wind direction, estimated precipitation and the current weather were recorded at least twice a day, at 0800 and 2000, during all three phases of the study.

Data on aircraft flying across the study area were also recorded during all three phases of the study. Identification of the aircraft, its direction of flight, its estimated elevation and location in relation to sheep in the area were noted as well as the date and time of day. If sheep were present, their reaction to the aircraft was recorded.

Observations of other bird and mammal species in the study area during the three phases of the simulator experiment were also recorded.

Acoustical Measurements

In order to determine the relative loudness of the simulator sounds at the mineral licks, acoustical measurements were made after the conclusion of the simulator experiment. All measurements were taken with a sound level meter (decibel meter) type 2205 using a wind screen, the "C" weighting network and "slow" speed. In addition to simulator sound levels, the background noise levels, wind speed and direction, temperature and comments concerning the sounds audible to human ears were also recorded.

At mineral lick L-4 acoustical measurements were made at six locations: at the three major licking areas located in the north lick, mid-lick and south lick, on the bank above the north lick where a trail enters the lick, at the highest point on the bank above the mid-lick (Plate 2), and on the bank above the south lick along another sheep trail. Six acoustical measurements were also made at mineral lick L-18, at the west, mid and east licks at points along the base of the gravel bank composing the lick and at three corresponding locations on top of the bank above the lick (Plate 3). In addition, sound level readings were taken on a mountain slope about 1/4 mile north of L-18 where sheep were seen prior to crossing into the lick and on another slope about 1/2 mile west of the simulator where sheep were observed grazing and resting. One other sound measurement was made about 1/2 mile north of the simulator on the bench above the river.

Distances to the locations at the licks where acoustical measurements were made were measured with a 100-foot tape or calculated by triangulation.

Data Analysis

Because sheep were constantly entering and leaving the licks and individuals could not be recognized, it was difficult to determine actual numbers of sheep using a lick on a given day. Therefore numbers of sheep-hours were calculated as a measurement of daily lick use which was comparable between different days of the experiment. Sheep-hours were calculated by multiplying the number of sheep observed during each 30-minute observation period by 0.5 and summing these figures for each day.

Maximum and minimum numbers of different individuals at a lick on a given day were estimated. An increase in the number of sheep seen from one observation period to the next generally indicates that different individuals have entered the lick. The summation of the number of different individuals observed on a given day was an estimation of the maximum number of individuals using the lick that day. However, changes in numbers of sheep occurring between consecutive observation periods may not always be due to individuals entering or leaving the lick. Sheep in the lick may have been out of sight, (e.g. behind rocks or in a gully) during a given observation period. If the possibility of this situation existed, the observation was eliminated. The summation of the numbers of different sheep seen on a given day minus any questionable observations was an estimation of the minimum number of sheep using the lick that day.

If a sheep left the lick but returned the same day, it would be counted as two individuals. Thus, the estimated numbers of sheep may be larger than the actual numbers of different individuals using a lick on a given day.

In addition to numbers of sheep seen at the licks, observations of sheep activity were recorded. From data on the number of resting versus active animals, an average percentage of resting sheep was calculated according to the following procedure: percentages of resting sheep determined for each 30-minute observation period, multiplied by 0.5, were summed for a given day and divided by the total number of hours that sheep were observed at the lick during that day.

In order to equalize the number of hours of observation made each day, only data from a 16-hour period (0400-2000) were used in the calculation of sheep numbers and activity. About 99% of all sheep hours recorded during 24-hour observation periods were made between 0400 and 2000, indicating that most sheep visit licks during the day rather than at night.

Sheep were observed a minimum of 16 hours a day (from 0400 to 2000) on each day of the simulator experiment with two exceptions: on 16 July, observations were made from 1500 to 2400 and on 21 July, observations were made from 0530 to 1300. When mean values and statistical tests were computed for Phase I, the data from these two days were combined.

Data on sheep numbers and activity at the two licks were subjected to statistical analysis. Descriptions and computations of the statistical tests used are found in the Appendix.

RESULTS

Acoustical Measurements

Sound level measurements made with a decibel meter at mineral licks L-4 and L-18 and at three adjacent areas indicate that sheep at different locations were subjected to varying levels of sound from the simulator (Table 3). At mineral lick L-4, the closest lick to the simulator, sound pressure level readings were 2 to 22 decibels higher than background noise levels. The lowest readings were obtained at the north lick, where the sounds of the simulator were muffled by the roar of the river. The highest sound pressure levels were measured at the mid-lick, which was directly opposite and closest to the simulator. Sound pressure levels at the top of the lick were similar to one another, although background noise levels above the north lick were slightly higher due to the proximity of the river.

The sounds of the simulator were quite audible to human ears at locations where acoustical measurements were made. Sounds also varied in intensity.

At mineral lick L-18, the sounds of the simulator were at a level too low to be measured. Readings made when the simulator was turned on did not differ from background noise levels. Human ears could faintly hear the sounds of the

Table 3. Sound pressure level readings measured at simulator experiment study area.

Location	Distance from Simulator in Feet	Background Sound Level in Decibels	Simulator Sound Level in Decibels
		Mineral Lick L-4	
North Lick	1780	60	62 - 64
Mid-Lick	1460	51	66 - 73
South Lick	1790	45	58 - 65
Top of N. Lick	2090	52	62 - 64
Top of Mid-Lick	2150	48	62 - 68
Top of S. Lick	2480	48	62 - 66
		Mineral Lick L-18	
West Lick	4690	45 - 50	45 - 50
Mid-Lick	3720	35 - 46	35 - 46
East Lick	3020	50 - 56	50 - 56
Top of W. Lick	5010	52 - 58	52 - 58
Top of Mid-Lick	4050	45 - 55	45 - 55
Top of E. Lick	3350	50 - 66	50 - 66
		Other Locations	
S. facing slope est. 1 mile SW of simulator	not measured	40 - 44	40 - 44
E. facing slope est. 3/4 mile SW of simulator	not measured	45 - 55	45 - 55
Bench above river est. mile N of simulator	not measured	55 - 65	55 - 65

simulator at L-18. However, the sounds varied greatly in intensity and were not always audible above the sounds of the creek which flowed adjacent to the lick.

Sound measurements taken from the slopes southwest of the simulator and on the bench north of the simulator also showed no difference between simulator and background sound levels. The simulator was again faintly audible to human ears at these locations.

Meteorological factors which can affect sound transmission were fairly consistent while sound measurements were being made. The temperature ranged from 49° to 52°F. At mineral lick L-4, the wind was from the north at 0 to 4 mph. At the other localities, the wind was from the north at 0 to 6 mph. Wind velocities above 4 mph affected decibel readings although a wind screen was used. Therefore, background noise levels at these locations were measured as a range of sound.

Weather Data

Meteorological measurements made at the study area show the great variations in weather conditions which occurred during the simulator experiment (Table 4). Control Phase I was characterized by cold, wet, windy weather. Skies were generally overcast and rain or snow fell for 4 days out

Table 4. Weather observations recorded during the simulator experiment.

Date	Mean Temp. (°F)	Est. Wind Velocity (mph)	Wind Direction	% Cloud Cover	Precipitation
		Control Phase I			
16 July	57	1 to 5	S	100	None
17 July	44	5 to 10	N	100	Rain
18 July	42	1 to 5	N	80	Snow
19 July	39	5 to >10	SW,N	100	Rain/snow
20 July	38	>10	S,N	100	Rain/snow
21 July	43	5 to 10	N	90	None
Mean	43.8			95	
		Experimental Phase II			
23 July	58	5 to 10	SW	40	Trace
24 July	64	5 to 10	SW	30	None
25 July	66	1 to >10	S	60	None
26 July	66	1 to 5	S	40	None
27 July	66	1 to 5	N	25	None
Mean	64			39	
		Control Phase III			
2 August	51	0	-	5	None
3 August	51	1 to 5	S	50	None
4 August	56	1 to 5	S	55	None
5 August	64	1 to 5	S	80	None
Mean	55.5			47.5	

of 6. Strong winds from the north blew frequently. The mean temperature for this phase was 20° F colder than the mean temperature of the experimental phase. Mosquitoes were present only during one morning and afternoon.

During experimental Phase II and control Phase III, the weather was generally warm, sunny and calm. Winds from the south blew less frequently and with less force. Mosquitoes were numerous every day.

Temperature was the only major difference between experimental Phase II and control Phase III. The mean temperature of the experimental phase was 9° F higher than that of the control phase.

Lick Use

Disturbance of sheep using a mineral lick may result in a reduction of actual numbers, disruption of normal activity patterns, or avoidance of the lick by certain segments of the population. Numbers of sheep, their activity and composition of the population at the licks were recorded at both licks observed during the simulator experiment.

Mineral Lick L-4

Mineral lick L-4 was of primary interest because high levels of sheep activity had been observed there prior to the onset of the simulator experiment. The simulator was placed approximately 1/4 mile west of the lick (Plate 1) and acoustical measurements show that L-4 was the only lick subjected to measurable sound levels (Table 3).

Sheep were observed every day at L-4 during control Phase I, before the simulator was brought to the study area. During experimental Phase II, sheep continued to use the lick. After the simulator was turned on, the first sheep to enter L-4 appeared to be nervous and jumpy. They bedded down on a trail leading to the lick for at least 30 minutes. However, within an hour, one sheep was at the mid-lick directly across from the simulator. An estimated minimum of 21 sheep came to the lick during the first day that the simulator was turned on. Sheep were seen at L-4 every day throughout experimental Phase II and control Phase III.

Sheep Numbers

During the three phases of the simulator experiment, numbers of sheep-hours and estimated minimum and maximum numbers of individuals were calculated for each day of observation (Table 5).

Numbers of sheep using the lick varied widely from day to day. During each phase, both large and small numbers of

Table 5. Numbers of sheep using mineral lick L-4 during the simulator experiment between the hours of 0400 and 2000.

Date	Number of Sheep-Hours	Estimated Number of Individuals Minimum	Estimated Number of Individuals Maximum
		Control Phase I	
16 July	56.5+	13+	15+
17 July	1.5	3	3
18 July	45.0	13	13
19 July	44.0	15	17
20 July	139.0	33	35
21 July	132.0+	60+	73+
Total	418.0	137	156
⊕Mean	83.6	27.4	31.2
⊕Standard Deviation	77.3	27.7	33.8
		Experimental Phase II	
23 July	133.0	21	23
24 July	52.0	15	17
25 July	47.5	8	8
26 July	50.5	13	13
27 July	6.0	1	1
Total	289.0	58	62
Mean	57.8	11.6	12.4
Standard Deviation	46.2	7.5	8.4
		Control Phase III	
2 August	27.5	7	7
3 August	106.5	16	23
4 August	97.5	18	21
5 August	7.0	5	5
Total	238.5	46	56
Mean	59.6	11.5	14.0
Standard Deviation	49.8	6.5	9.3

+ Minimum values: observations made 16 July from 1300-2000 and on 21 July from 0530-1300.

⊕ Calculated considering 16 July and 21 July as a single day.

animals were observed. There was more variation in lick use between days than between the control and experimental phases. There was no significant difference (P>0.05) in the number of sheep-hours and estimated number of individuals calculated for the three phases of the experiment (Appendix). The sounds of the simulator did not depress the numbers of sheep using mineral lick L-4.

Sheep Activity

During the simulator experiment, three aspects of sheep activity at L-4 were recorded: relative numbers of active versus resting animals, the length of time individuals spent at the lick and locations of sheep moving into and out of and across the lick.

From 30-minute interval observations of active and resting sheep at L-4 an average percentage of sheep resting was calculated for each day of the experiment (Table 6). Sheep disturbed by the sounds of the simulator might be expected to spend less time resting at the lick. But the highest average percentages of resting sheep were observed during the experimental phase; days when no sheep were seen resting at the lick occurred only during the two control phases.

These differences may be related to many factors such as weather. The mean temperature during Phase II was more

Table 6. Average percent of sheep resting per day at mineral lick L-4 during the simulator experiment.

Control Phase I		Experimental Phase II		Control Phase III	
Date	Average % Resting	Date	Average % Resting	Date	Average % Resting
16 July	6+	23 July	6	2 August	0
17 July	0	24 July	26	3 August	12
18 July	5	25 July	10	4 August	14
19 July	1	26 July	16	5 August	0
20 July	13	27 July	17		
21 July	10+				
⊕Mean	5.4	Mean	15.4	Mean	6.5
⊕Standard Deviation	5.3	Standard Deviation	7.6	Standard Deviation	7.6

+ Minimum values: Observations made 16 July from 1300-2000 and on 21 July from 0530-1300.

⊕ Calculated considering 16 and 21 July as a single day; the average % of sheep resting was 8% for these two days combined.

than 20° higher than Phase I and almost 10° F higher than Phase III and cloud cover was generally less (Table 4). The warm sunny weather was probably not the only factor affecting resting sheep or a more striking difference would have been observed between Phase I and Phase III when weather conditions also varied greatly. Group size could also affect percentages of resting sheep. If a small group with one or two resting animals were observed, a relatively large percentage of resting sheep would be recorded. Conversely, if a large group with one or two resting animals were observed, a relatively small percentage of resting sheep would be recorded.

Other factors such as social facilitation or individual motivation may influence sheep to rest at a lick. However, the sounds of the simulator apparently had no depressing effect on sheep resting at mineral lick L-4.

It was difficult to distinguish between individual sheep and only limited data were collected on the length of time that individuals or groups of individuals stayed at mineral lick L-4. Occasionally a single sheep or one group of sheep would enter the lick, spend an interval of time, and leave without being joined by other individuals. During the three phases of the simulator experiment, observations of this kind were made on 22 groups of sheep at L-4 (Table 7).

Table 7. Number of hours (to the nearest .5 hour) that groups of sheep stayed at mineral lick L-4 during the simulator experiment.

Control Phase I		Experiment Phase II		Control Phase III	
Group Size & Kind	# of Hours Spent at Lick	Group Size & Kind	# of Hours Spent at Lick	Group Size & Kind	# of Hours Spent at lick
1 ram	0.5	2 ewe + lamb	0.5	3 "ewes" + lamb	1.0
2 ewe + lamb	0.5	2 "ewes"	0.5	1 unknown	1.5
1 ram	2.5	2 ewe + lamb	2.0	3 "ewes"	2.5
2 ewe + lamb	3.0	2 ewe + lamb	2.5	1 "ewe"	3.0
1 ram	3.5	2 ewe + lamb	3.5	2 "ewe" + ram	4.5
6 "ewes" + lambs	3.5	1 ram	6.0	2 ewe + lamb	6.5
9 "ewes" + lambs	3.5	6 "ewes" + lambs	6.5		
8 rams, "ewes" + lambs	4.5				
8 rams, "ewes" + lambs	8.0				
Mean	3.3	Mean	3.1	Mean	3.2
Standard Deviation	2.2	Standard Deviation	2.4	Standard Deviation	2.0

The length of time calculated from this sample is only an estimate of the actual time spent at the lick. Since observations of sheep were made only every 30 minutes, the length of time individuals spent at the lick was recorded to the nearest 30 minutes; individuals remaining at the lick for less than 30 minutes were recorded as being at the lick for 30 minutes. The time sheep spent at the lick was calculated the same way during all three phases and should not have influenced the comparative results.

There was no significant difference (P>0.05) between the mean number of hours spent at mineral lick L-4 during the control and experimental phases (Appendix). This suggests that the sounds of the simulator had no measurable effect on the length of time individual sheep spent at the lick.

Sheep using mineral lick L-4 usually entered and left the lick at specific locations and spent a majority of their time at specific areas within the lick. The three major licking areas used at L-4 were designated as the north lick, mid-lick (Plate 2) and south lick. Sheep typically entered at the top of the north lick or mid-lick, moved across the lick from north to south and left at the top of the south lick. The mid-lick was used most frequently. Because of this use pattern, the simulator was situated nearest to this portion of the lick.

The number of sheep-hours spent at each licking area was recorded during Phase II and Phase III (Table 8). During both phases, sheep spent most of their time at the mid-lick. But during the experimental phase, the percentage of time spent at the mid-lick was significantly less ($P<0.01$) than the time spent at the mid-lick during control Phase III (Appendix). If an actual difference in time spent at the mid-lick does exist, it may be due to disturbance. Sounds of the simulator were most audible at the mid-lick and some sheep may have moved to the north or south licks where sound levels were lower.

Composition

A total of 153 sheep coming to mineral lick L-4 were classified during the simulator experiment (Table 9). All segments of the population were present during all three phases of the simulator experiment. Ewes with young lambs may be more sensitive to disturbance than other sheep (Murie, 1944). However, there was no decline in the number of lambs seen during the experimental phase. By late July when the study was conducted, lambs were old enough to be quite independent of their mothers.

Table 8. Location of sheep at mineral lick L-4 during two phases of the simulator experiment.

Location	# of Sheep-Hours Observed Total #	%
	Experimental Phase II	
North Lick	33.5	20.4
Mid-Lick	88.0	53.7
South Lick	42.5	25.9
Total	164.0	100
	Control Phase III	
North Lick	23.0	10.0
Mid-Lick	189.0	82.4
South Lick	17.5	7.6
Total	229.5	100

Table 9. Sample composition of the sheep population using mineral lick L-4 during the simulator experiment.

Phase	Total # Classified	# Rams	% Rams	# "Ewes"	% "Ewes"	# Lambs	% Lambs
Control Phase I	55	16	29	21	38	18	33
Experimental Phase II	53	2	4	31	59	20	37
Control Phase III	45	1	2	32	71	12	27
Total for all Phases	153	19	12.4	84	54.9	50	32.7

Fewer large rams were classified during both Phase II and Phase III. Some rams may have been disturbed by the simulator sounds to the extent that they did not return during Phase III. Or, the reduction in lick use by rams may have been a seasonal change or the result of sexual differences in lick use. Rams using a mineral lick in the Alaska Range spent less time at the lick than did lactating ewes (Heimer and Smith, 1972).

Mineral Lick L-18

Mineral lick L-18 was located approximately 3/4 mile southwest of the simulator (Plate 1). Sheep did not use this lick as frequently as L-4 prior to the onset of the simulator experiment. Acoustical measurements (Table 3) show that simulator sounds at L-18 were no louder than background noise levels, primarily sounds of the nearby creek. The sounds of the simulator were faintly audible to human ears, varied in intensity, and were probably detectable by sheep at L-18.

Sheep at L-4 were subjected to measurable amounts of sound, but sheep at L-18 were exposed to low levels of auditory disturbance. As sound levels were different at the two licks, a difference in lick use should have been observable if sheep were disturbed by simulator sounds. Thus, a comparison of relative lick use at L-4 and L-18 provides additional insight into whether or not the sounds of the simulator affected sheep using mineral lick L-4.

Sheep Numbers

Sheep utilization at mineral lick L-18 during the simulator study, calculated in sheep-hours and estimated minimum and maximum numbers of individuals, is presented in Table 10.

No sheep were observed at the lick for 4 days during Phase I. The size of the subpopulation using L-18 may have been small: during the two control phases, only 155.5 sheep-hours were recorded at L-18 as compared with 656.5 sheep-hours recorded at L-4 during the same time period. Sheep surveys showed fewer sheep in the vicinity of L-18 when compared with areas near L-4. Factors motivating sheep to visit a lick also could have contributed to the lack of lick use observed during Phase I.

At L-18 sheep were observed every day during Phase II and III. There was no significant difference ($P>0.05$) between mean numbers of sheep-hours or estimated numbers of individuals observed at L-18 during these two phases.

Although differences in the sizes of the subpopulations using the two licks preclude day-to-day comparisons of sheep numbers, some similarities between the two licks can be seen.

Table 10. Number of sheep using mineral lick L-18 during the simulator experiment between the hours of 0400 and 2000.

Date	Number of Sheep-Hours	Estimated Number of Individuals Minimum	Maximum
	Control Phase I		
16 July	5.5+	11+	11+
17 July	0.0	0	0
18 July	0.0	0	0
19 July	0.0	0	0
20 July	0.0	0	0
21 July	14.5+	13+	13+
Total	20.0	24.0	24.0
⊕Mean	4.0	4.8	4.8
⊕Standard Deviation	6.3	6.6	6.6
	Experimental Phase II		
23 July	82.5	22	28
24 July	19.0	7	7
25 July	15.5	5	5
26 July	7.0	8	8
27 July	56.5	14	18
Total	180.5	56.0	66.0
Mean	36.1	11.2	13.2
Standard Deviation	32.1	6.9	9.7
	Control Phase III		
2 August	42.5	12	12
3 August	9.0	4	4
4 August	32.0	10	10
5 August	52.0	17	19
Total	135.5	43.0	45.0
Mean	33.8	10.7	11.2
Standard Deviation	22.4	4.2	6.2

+ Minimum values: Observations made 16 July from 1300-2000 and on 21 July from 0530-1300.

⊕ Calculated considering 16 July and 21 July as a single day.

At both licks sheep were observed after the simulator was turned on. Numbers of sheep recorded varied widely from day to day at both licks. There was no statistically significant difference between numbers of sheep-hours or estimated numbers of individuals observed during Phase II and Phase III at both L-18 and L-4.

Sheep Activity

Sheep activity at mineral lick L-18 was measured by the same criteria used at L-4. Relative numbers of resting versus active animals were calculated, the number of hours that individuals remained at the lick was determined and locations of sheep entering, leaving and moving across the lick were recorded.

An average percent of sheep resting at L-18 was calculated for each day of the simulator experiment (Table 11). During the control phases, no sheep were observed resting at the lick. But sheep were seen resting at L-18 during the first three days of the experimental phase.

These observations were similar to events recorded at L-4 (Table 6) where higher percentages of resting sheep were observed during the experimental phase. Also, at both licks unusually high percentages of resting sheep were recorded on 24 July. These correlations suggest that external factors which affect both licks simultaneously, such as weather,

Table 11. Average percent of sheep resting per day at mineral lick L-18 during the simulator experiment.

Control Phase I		Experimental Phase II		Control Phase III	
Date	Average % Resting	Date	Average % Resting	Date	Average % Resting
16 July	0	23 July	5	2 August	0
17 July	-	24 July	20	3 August	0
18 July	-	25 July	6	4 August	0
19 July	-	26 July	0	5 August	0
20 July	-	27 July	0		
21 July	0				
Mean	0		6		0
Standard Deviation	0		8		0

may influence sheep to rest at the licks.

The length of time spent at L-18 by individual sheep was derived for 12 groups during Phase II and Phase III (Table 12), employing the same methods used for L-4. There was no significant difference (P>0.05) between the length of time individuals spent at L-18 during Phase II and Phase III (Appendix). There was also no significant difference (P>0.05) between the length of time individuals spent at L-4 and L-18 (Appendix), suggesting that the sounds of the simulator did not affect the length of time sheep spent at a lick.

Sheep visiting mineral lick L-18 used typical patterns to enter, leave and move across the lick. Because of the nature of the terrain surrounding the lick, sheep entered and left L-18 at its western end. They came from the mountain slopes across the creek north of the lick or from the mountain slopes west of the lick and returned to these areas after leaving the lick.

L-18 was arbitrarily divided into a west lick, mid-lick and east lick (Plate 3). The locations of sheep at L-18 were recorded during Phase II and III and numbers of sheep-hours were calculated for each location (Table 13). There was a significant difference (P<0.01) between locations used during the two phases (Appendix). The mid-lick was most frequently used during the experimental phase but the east lick was used

Table 12. Number of hours (to the nearest 0.5 hour) that groups of sheep stayed at mineral lick L-18 during two phases of the simulator experiment.

Experimental Phase II		Control Phase III	
Group Size & Kind	# of Hours Spent at Lick	Group Size & Kind	# of Hours Spent at Lick
1 ram	0.5	2 unknown	1.5
2 "ewes"	0.5	2 rams	3.0
1 ewe	1.0	2 ewes + lamb	3.5
2 ewes + lamb	1.0	8 unknown	4.0
6 ewes + lambs	2.0		
1 "ewe"	3.0		
3 "ewes" + lambs	4.5		
2 ewes + lamb	5.5		
Mean	2.3	Mean	3.0
Standard Deviation	1.9	Standard Deviation	1.1

Table 13. Location of sheep at mineral lick L-18 during two phases of the simulator experiment.

Location	Experimental Phase II # of Sheep-Hours Observed		Control Phase III # of Sheep-Hours Observed	
	Total #	%	Total #	%
West Lick	25.0	25.1	27.0	20.0
Mid Lick	40.0	40.2	18.5	13.7
East Lick	34.5	34.7	89.5	66.3
Total	99.5	100.0	135.0	100.0

most often during the control phase.

A shift in the location of sheep was also observed at mineral lick L-4 (Table 8). At both licks during Phase III a majority of sheep-hours were recorded at areas closest to the simulator: the mid-lick at L-4 and the east lick at L-18 (Table 3). When the simulator was on during Phase II, fewer sheep-hours were recorded at these two locations, suggesting that sounds of the simulator could have disturbed some individuals. Sheep may have moved to areas of the licks where simulator sounds were less audible. Although simulator sound levels were too low to be measured at L-18, the east lick may have been subjected to more auditory disturbance as it was about 700 feet closer to the simulator than other lick areas at L-18.

The shift in location of sheep at both licks could have been due to factors other than auditory disturbance. Sheep may have individual preferences for specific licking areas and different groups of individuals may have visited the lick during the three phases of the experiment. Also, the presence of other sheep at a lick could influence the movements and location of incoming sheep.

Composition

A total of 76 sheep were classified at mineral lick L-18 during Phase II and Phase III following the same criteria that was used at L-4 (Table 14). During both phases of the experiment, all segments of the population were present, although fewer large rams were classified than "ewes."

Composition data collected at L-18 was quite similar to observations made at L-4 (Table 15). At both licks all segments of the population were present during Phase II and III. Approximately the same proportion of "ewes" were classified at both licks. More lambs were classified at L-4 but a similar decline in the numbers of lambs classified occurred at both licks. More large rams were classified at L-18, but at both licks the number classified remained approximately the same during Phases II and III.

These similarities and the lack of a distinctive difference at L-4 during the experimental phase suggest that the simulator did not prevent certain sex and age groups from entering the lick.

Sheep in Vicinity of the Licks

During all three phases of the simulator experiment, sheep were observed in the vicinity of mineral licks L-4

Table 14. Sample composition of the sheep population using mineral lick L-18 during two phases of the simulator experiment.

Phase	Total # Classified	# Rams	% Rams	# "Ewes"	% "Ewes"	# Lambs	% Lambs
Experimental Phase II	35	6	17	19	54	10	29
Control Phase III	41	7	17	30	73	4	10
Totals for all Phases	76	13	17	49	65	14	18

Table 15. A comparison of sheep classified at mineral lick L-4 and mineral lick L-18 during the simulator experiment.

	Phase II		Phase III		Total
	L-4	L-18	L-4	L-18	#
# rams	2	6	1	7	16
% rams	4	17	2	17	
# "ewes"	31	19	32	30	112
% "ewes"	59	54	71	73	
# lambs	20	10	12	4	46
% lambs	37	29	27	10	
Total #	53	35	45	41	174

and L-18. Observations summarized for each phase of the experiment were plotted on a map of the study area (Figures 1, 2 and 3).

Some of the animals observed were sheep moving to and from mineral licks. In the vicinity of L-18 sheep were most frequently seen on the east-facing mountain slopes about 3/4 mile west and southwest of the simulator. Sheep were observed grazing and resting along these slopes; several individuals moved to mineral lick L-18 from these areas. Measurements made of simulator sound levels were no higher than background noise levels at two locations along the mountain slopes where sheep were often seen. However, the sounds of the simulator were very faintly audible to the human ear at these locations. More sheep were observed at these locations during Phase II (Figure 2) than during control phases (Figures 1 and 3), suggesting that the sounds of the simulator did not disturb sheep using these areas.

Observations of sheep in the vicinity of mineral lick L-4 were limited because of the surrounding terrain. Much of the plateau country adjacent to the eastern edge of L-4 was not visible from the observation area. Sheep in the vicinity of L-4 were usually seen as they crossed the mountain slope approximately 1/2 mile east of the lick. More sheep were observed in this area during Phase I (Figure 1); but

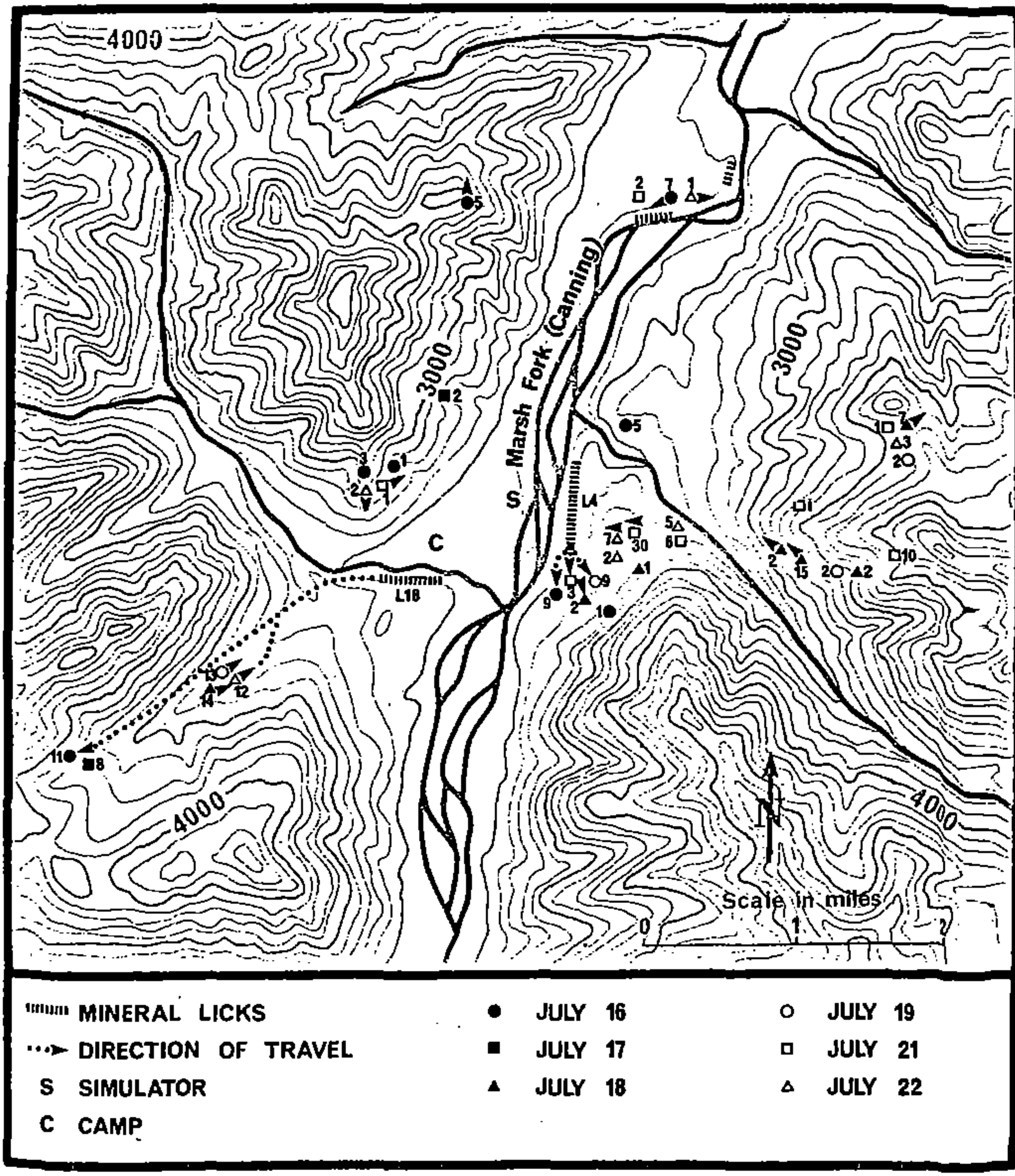

FIGURE 1 GROUPS OF SHEEP OBSERVED IN THE VICINITY OF THE LICKS DURING PHASE I OF THE SIMULATOR EXPERIMENT.

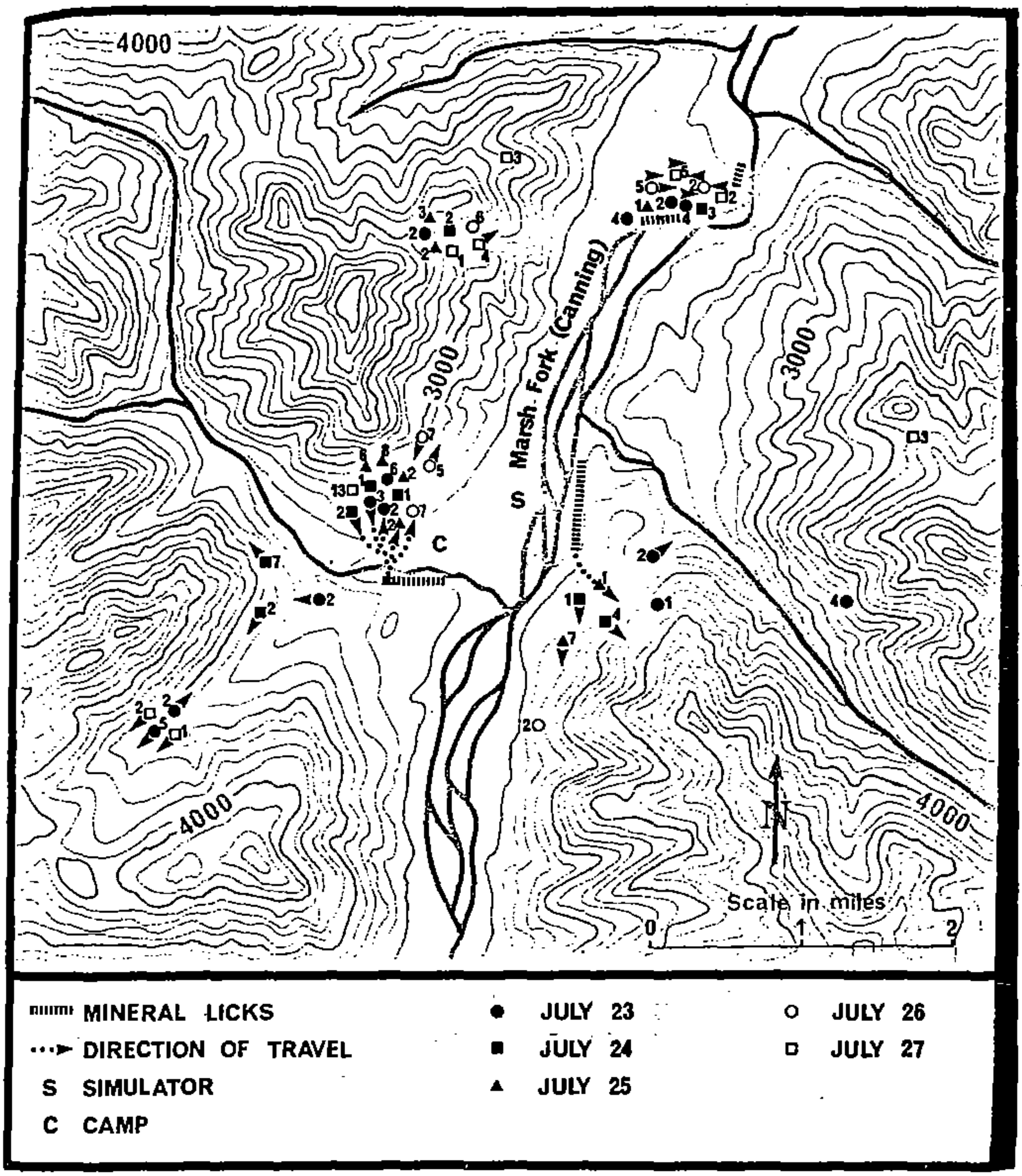

FIGURE 2 GROUPS OF SHEEP OBSERVED IN THE VICINITY OF THE LICKS DURING PHASE II OF THE SIMULATOR EXPERIMENT.

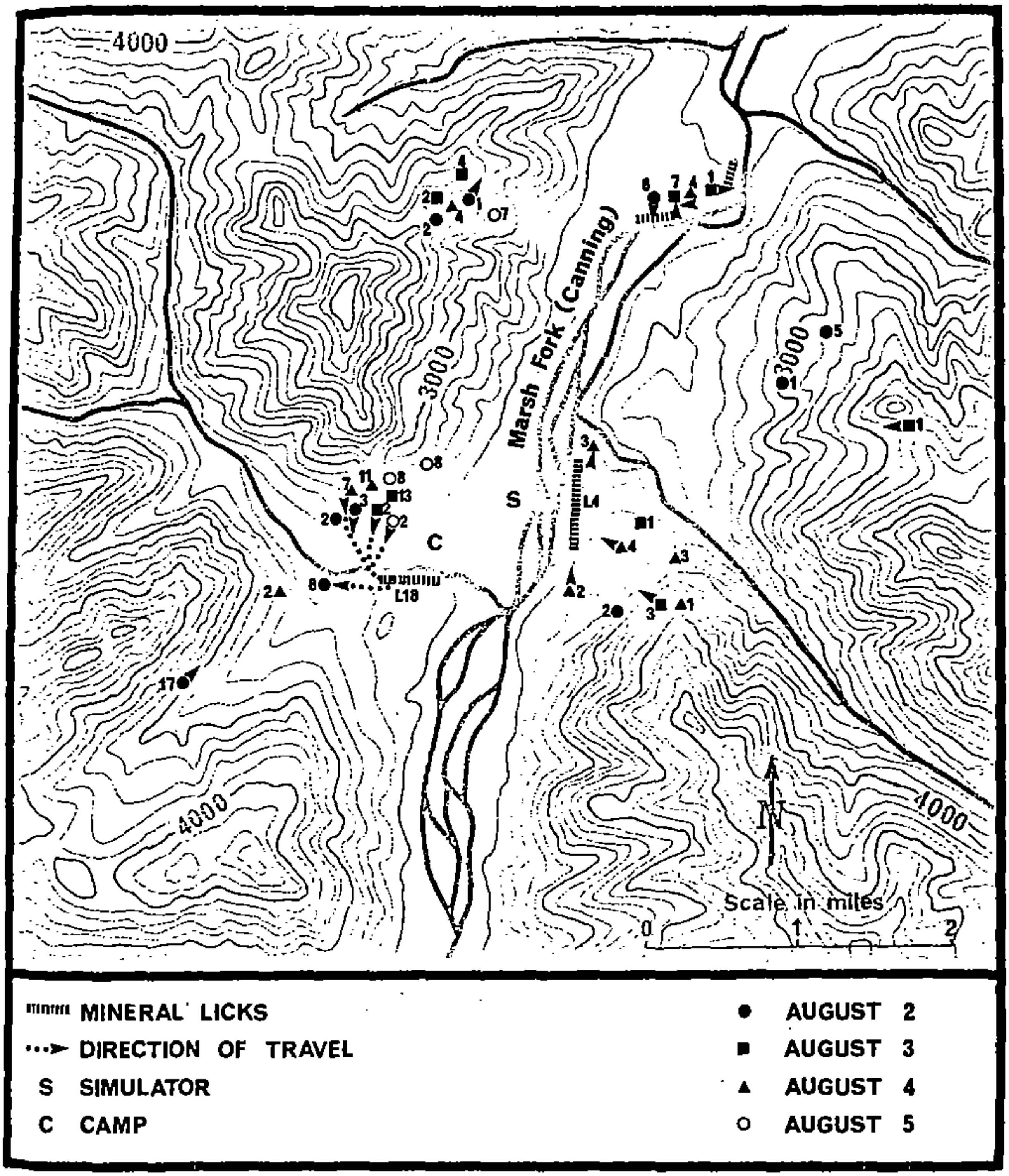

FIGURE 3 GROUPS OF SHEEP OBSERVED IN THE VICINITY OF THE LICKS DURING PHASE III OF THE SIMULATOR EXPERIMENT.

there appeared to be no great difference in numbers of sheep seen in the vicinity of L-4 during Phase II and Phase III (Figures 2 and 3). No acoustical measurements were made east of L-4; but because simulator sound levels were not measurable 1/2 mile away from the simulator, this location presumably was subjected to minimal sound levels. Even if faintly audible, the sounds apparently had no drastic effect on sheep using this area.

Sheep seen approximately 2 miles north of the simulator on the west side of the river were visiting a mineral lick not included in the study. Animals observed there and at other locations during the simulator experiment were probably too far away from the simulator to be affected by its sounds.

Other Sound Disturbances

In addition to being subjected to the continuous sounds of the simulator, sheep in the study area were exposed to other artificial sounds. Aircraft flying in the vicinity of the licks were a major source of possible disturbance. Also, short experiments were carried out to test the effects of sudden sounds on sheep using mineral licks.

Aircraft

During the simulator experiment 46 aircraft were observed flying over the study area. Field crews working in the vicinity were responsible for a majority of aircraft seen. These crews were using Bell 206 helicopters, a Fairchild-Hiller 1100 helicopter and a Cessna 185. In addition, hunters and unidentified aircraft were observed.

Sheep reactions to the aircraft were observed during all three phases of the simulator experiment (Table 16). The recorded reactions involved helicopters in all but one case. Reactions were classified as strong if the sheep ran, mild if the sheep looked toward the sound, or none if there was no response.

Although the effects of important factors such as wind speed and direction, local terrain and prior experience of the sheep were not known, the recorded reactions show some correlation with distance of the aircraft from the sheep. Sheep usually showed strong reactions when a helicopter flew within 150 yards of them at low elevations. However, sheep did not always react negatively to aircraft at close range. On 28 August a Fairchild-Hiller 1100 helicopter landed at the mid-lick of L-4 as acoustical measurements were being made. While the engine was still running, a ewe began walking toward the helicopter. She stopped once, then

Table 16. Some reactions of sheep to aircraft during the simulator study.

Type of Aircraft	Approx. Elevation Above Sheep (Feet)	Approx. Distance From Sheep (Feet)	Reaction to Aircraft
	Phase I		
Piper aircraft 11	-	-	Mild
Bell 206 helicopter	300	300	None
Bell 206 helicopter	landed	450	Strong
Bell 206 helicopter	landed	150	Strong
FH 1100 helicopter	landed	1500	Mild(few); None(most)
	Phase II		
FH 1100 helicopter	landed	1500	Mild(1); None(5)
Bell 206 helicopter	75	300	Strong
Bell 206 helicopter	-	-	Strong
Bell 206 helicopter	0	2700	Mild(1); None(8)
Bell 206 helicopter	-	150	None
	Phase III		
FH 1100 helicopter	1000	5400	None
FH 1100 helicopter	50	directly over	Strong
FH 1100 helicopter	150	directly over	Strong
Bell 206 helicopter	landed	1200	Mild
FH 1100 helicopter	50	2700	Mild
Bell 206 helicopter	(low)	300	Strong
FH 1100 helicopter	2000	5400	None
FH 1100 helicopter	1500	4200	Mild(6); None(5)
FH 1100 helicopter	landed	2700	None

continued to walk within 100 yards of the noisy machine. She showed no signs of disturbance until the engine sound level increased during takeoff. Then she ran up the slope above the mid lick. Other sheep on the north lick also ran when the helicopter flew about 50 yards lateral to them.

Sound Experiments

Two short experiments were conducted on groups of sheep at mineral lick L-4 to test their reactions to sudden sounds of the simulator. The first was conducted on 22 August, 17 days after the simulator had last been operating. Therefore, sheep at L-4 had not been subjected to simulator sounds for more than two weeks. A second experiment was conducted three days later on 25 August. Reactions to each separate component and to the total sounds of the simulator were recorded.

During both experiments the weather was mostly sunny with temperature about 69°F. During the first experiment there was a north wind of 6 mph gusting to 12 mph. During the second experiment the wind was from the north at 0 to 4 mph, gusting to 6 mph.

During the first experiment 12 sheep (4 rams, 4 ewes, and 4 lambs) were present at the mid-lick of L-4. All were engaged in feeding or licking when the simulator was turned on. Their reactions to the separate simulator components and all components played simultaneously are presented in Table 17. Only two components and the sum of the sounds elicited reactions from sheep at the lick. The bypass and scrubber components, which were measured as having the loudest sounds (Table 1), caused animals to lift their heads and look toward the sound source. Only one sheep responded to the sum of the sounds. All reactions were mild; no animals ran or appeared to be greatly disturbed by the sudden sounds of the simulator.

Prior to this experiment, a Bell 206 helicopter flew by approximately 100 yards west of L-4. At least 6 of the 12 sheep at the lick reacted by running. About 30 minutes after the termination of the experiment, the helicopter returned. As it passed the lick, all 12 sheep ran for approximately 10 seconds, then resumed licking or feeding.

During the second experiment the components were played in a different sequence. One ewe and lamb were licking at the mid lick of L-4 when the simulator was turned on. These sheep showed more reaction to the sudden sounds than did animals observed during the first experiment (Table 18). They looked toward the sound of the high frequency exhaust, as well as the bypass, scrubber and all sounds together. Orientation toward the sounds also lasted longer. However, all reactions were mild. Neither sheep ran or appeared greatly disturbed by the sudden sound stimuli.

Table 17. Reactions of 8 sheep at mineral lick L-4 to the sudden sounds of the simulator.

Component	Sheep Reaction to Sound
Generator	No reaction.
Low Frequency Exhaust	No reaction.
Scrubber	At least five sheep lifted their heads and looked toward sound for about five to ten seconds, then resumed licking or feeding.
High Frequency Exhaust	No reaction.
High and Low Frequency Exhaust	No reaction.
Air Intake	No reaction.
By-pass	Ewe and lamb lifted their heads for about five seconds; after a few seconds a ram lifted his head for about three seconds. Animals then resumed licking or feeding.
All Sounds	Ewe which reacted to by-pass sound lifted her head for about seven seconds then resumed licking. No reaction from other sheep.

Table 18. Reactions of a ewe and lamb at mineral lick L-4 to sudden sounds of the simulator.

Component	Sheep Reaction to Sound
Generator	No reaction.
Air Intake	No reaction.
By-Pass	Ewe lifted head and looked toward sound for seventy-five seconds (the length of time the sound was on); lamb moved toward ewe, also looked toward sound; within ten seconds after sound was turned off ewe resumed licking; lamb lay down after about three seconds.
Scrubber	Both lifted their heads and looked toward sound. Ewe kept head lifted for about fifteen seconds; lamb lifted head for about forty seconds. Then both resumed licking.
High Frequency Exhaust	Both looked toward sound: ewe for about ten seconds, lamb for about fifteen seconds. Then both resumed licking.
Low Frequency Exhaust	No reaction.
High and Low Frequency Exhaust	No reaction.
All Sounds	Ewe looked toward sounds for about nineteen seconds, then resumed licking; lamb lying down did not react to sounds.

Other Species

During the simulator experiment birds and mammals in the study area were subjected to the sounds of the simulator. Limited observations of species other than sheep were recorded during each phase (Table 19).

Of the six species of mammals seen, three were observed during all three phases of the experiment. Arctic ground squirrels were numerous in the study area and did not seem to be disturbed by the sounds of the simulator. Their numbers and activity did not appear to decrease during the experimental phase. They adapted rapidly to the presence of humans.

Red foxes were also residents of the study area. A den containing four pups was located approximately 1 mile south of the simulator. During Phase I, adult red foxes were observed on four occasions hunting along the river and its western bank between the den and the simulator. The adults were not seen during Phase II, but one was observed hunting along the river during Phase III. The foxes may have been disturbed by sounds of the simulator and moved elsewhere to hunt. Canids have well-developed hearing which is important in hunting as well as in vocal communication (Mech, 1970); and foxes may be sensitive to sound disturbance. However, the den remained occupied throughout the experiment. Other factors, such as a decline in the availability of prey species,

Table 19. Other species observed at the study area during the simulator experiment.

		Number of Observations		
Common Name	Scientific Name	Control Phase I	Experimental Phase II	Control Phase III
		Mammals		
Arctic ground squirrel	*Citellus parryii*	Common	Common	Common
Red fox	*Vulpes fulva*	5	1	2
Caribou	*Rangifer tarandus*	2	1	3
Grizzly bear	*Ursus arctos*	1	0	0
Wolf	*Canis lupus*	1	0	0
Porcupine	*Erethizon dorsatum*	1	0	0
		Birds		
Sparrow	Unidentified species	Common	Common	Common
Gyrfalcon	*Falco rusticolus*	2	3	4
Raven	*Corvus corax*	3	3	1
Golden eagle	*Aquilla chrysaetos*	0	3	3
Upland plover	*Bartromia longicauda*	3	1	0
Mew gull	*Larus canus*	2	1	0
Northern shrike	*Lanius excubitor*	0	0	3
Green-winged teal	*Anas carolinesis*	1	1	0
Wheatear	*Oenathe oenathe*	1	0	0
Robin	*Turdus migratorius*	1	0	0
Arctic tern	*Sterna paradisaea*	0	1	0
Long-tailed jaeger	*Stercorarius longicaudus*	0	0	1

could have influenced hunting habits also.

During Phase II a large group of approximately 700 caribou moved up the Marsh Fork to within 2 miles of the simulator, then turned westward toward Pogopuk Creek. These animals were probably too far from the simulator to be affected by its sounds.

Twelve species of birds were seen in the study area during the simulator experiment. Of these, seven species were observed during one or both control phases as well as during the experimental phase.

Commonly observed species may have been residents of the area. Gyrfalcons probably nested nearby, as both juveniles and adults were observed. Green-winged teal ducklings and adults were seen in the small creek below the simulator during Phase I and Phase II. The three observations of northern shrike were of juvenile birds. The most frequently seen species were recorded during all three phases.

Ravens, gulls and a golden eagle were observed flying along the river within 100 yards of the simulator when it was turned on. The sounds did not appear to alter their flight patterns.

The effects of simulator sounds on birds have been reported in other studies. Reproductive success of lapland longspurs was not affected by the sounds of a simulator during an experiment in Canada (Gollop et. al., 1974). However, during another study, flocks of snow geese, exposed to simulator sounds while approaching decoys, circled and landed less often than did flocks not subjected to the sounds. Test flocks also wheeled sharply away and left the area more frequently than did control flocks (Gollop and Davis, 1974).

The limited data on birds and mammals observed during this study suggest that the simulator sounds had no major effects on these species.

DISCUSSION

Results of this experiment indicate that sheep using mineral lick L-4 in late July were not greatly disturbed by the simulated sounds of a compressor station. Sheep came into the lick while the simulator was turned on. There was no significant decline in sheep numbers at the lick during the experimental phase. The sounds of the simulator had no depressing effect on sheep resting at L-4 or on the length of time individuals spent at the lick. Some individuals may have moved to areas of the lick where sound levels were lower. All segments of the population were present at the lick throughout the study. Similar results were observed at mineral lick L-18.

Very little is known about how well sheep can hear, but Geist (1971) reports sheep reacting to the loud rumble of rock slides or avalanches. The mild reactions of individuals to sudden simulator sounds during the sound experiments indicate that sheep at L-4 were acoustically aware of sounds of the simulator.

Sheep on the study area had been subjected to large amounts of auditory disturbance (noise from aircraft) for at least 2 months prior to the onset of the simulator experiment. Numerous aircraft including a Fairchild-Hiller 1100 helicopter, a Bell 206 Jet Ranger helicopter and a Cessna 185 airplane had been used during field studies along the Marsh Fork since early May. Logistic support for a fisheries field camp located about 4 miles downstream from the study area was also supplied by helicopter. A Piper Navajo airplane and other aircraft travelling between Arctic Village and a field camp at Kavik usually followed a route along the Marsh Fork River. Also, hunters contributed to the air traffic in the area.

Additional biologists and engineering and survey crews were working in the vicinity of the study area during July and August. An average of more than three aircraft per day were observed flying in the vicinity of the mineral licks during the simulator study.

Acoustical measurements made of a Fairchild-Hiller 1100 helicopter near mineral lick L-4 gave an indication of the magnitude of noise levels to which sheep using this lick were exposed. A maximum sound pressure level of 78 decibels was recorded at the mid-lick as the helicopter flew north at 100 mph, 75 yards west and 50 feet above L-4. As the helicopter flew south, a maximum sound pressure level of 81 decibels was measured. The ambient noise level and meteorological conditions were almost identical to those recorded when simulator sounds were measured. Noise levels of the helicopter were 5 to 15 decibels higher than simulator sound levels recorded at the mid-lick of L-4 (Table 3).

Klein (1973) found that a Fairchild-Hiller 1100 helicopter cruising at 95 mph produced a sound pressure level of 81 decibels, and a Cessna 185 airplane cruising at 145 mph produced a sound pressure reading of 85 decibels. Both aircraft were flying 500 feet above the ground. The background noise levels varied from 20 to 30 decibels. These acoustical measurements indicate that sheep in the study area had been subjected to repeated noises at least as loud as simulator sounds prior to the beginning of the experiment.

Animals exposed to a repeated stimulus which is not accompanied by positive or negative reinforcement eventually will refrain from responding to the stimulus (Eibl-Eibesfeldt, 1970). This habituation to a repeated stimulus involves a decrease in intensity or number of responses (Hinde, 1966). Sheep at mineral lick L-4 may not have reacted strongly to the sounds of the simulator because prior exposure to repeated aircraft noise resulted in habituation to certain sound levels.

Habituation of sheep to loud sounds has been observed elsewhere. Lent and Summerfield (1973) observed the reactions of Dall sheep to dynamite detonations. Dynamite explosions 3.5 miles away produced sound levels averaging 105 decibels near the sheep. They stated: "Most animals interrupted their activities briefly ... Habituation was noticeable during the course of the day. That is, the intensity of the reactions tended to decrease somewhat with subsequent detonations." Sheep in this area had been subjected to noise disturbance by aircraft associated with the construction of the TransAlaskan pipeline since 1968, and may have become habituated to some sound levels prior to these observations.

Populations of sheep subjected to large amounts of aircraft disturbance have been observed during two other studies. Linderman (1972) recorded reactions to aircraft in a group of animals which had been exposed to an average of more than four aircraft per day. Reactions were unpredictable and ranged from lifting their heads to running wildly. Sheep appeared nervous whenever low-flying aircraft passed over, but they did not always run. Anderson (1971) also recorded sheep reactions to aircraft. In his study, animals were subjected to an average of 2.8 flights per day. Again, reaction varied from watching the aircraft to running. Although no correlation between reactions and distance of the aircraft was reported in these studies, the fact that sheep did not always react strongly to low-flying aircraft suggests that some habituation to sound disturbance had occurred.

During an experiment carried out in Canada in July 1972. to test the reaction of Dall sheep to the simulated sound of a gas compressor station, a group of male Dall sheep was apparently adversely affected by simulator sounds (McCourt et. al., 1974). Some behavioural patterns appeared to be altered and most of the sheep abandoned the range within approximately 1 mile of the sound simulator.

These results appear contradictory to those obtained during the Marsh Fork simulator experiment. Difference in prior exposure to loud sounds and differences in the areas studied may account for the conflicting results. The sheep observed during the 1972 Canadian simulator experiment apparently were not subjected to large amounts of aircraft traffic prior to the beginning of the experiment. The number of flights within 5 miles of the study area was estimated to be a maximum of 14 fixed-wing flights and 9 helicopter flights during 1971 and 1972 (John Russell, Renewable Resources Consulting Services Ltd., pers. comm.). Renewable Resources Consulting Services Ltd. caribou surveys were responsible for almost half of the total flights during the 2 years. In 1972, only three caribou surveys (two in early May, one in late June) were flown within a mile of the study area before the experiment began.

This amount of aircraft traffic is minimal when compared to the average of more than three aircraft per day recorded in the Marsh Fork study area. The Canadian sheep may have been affected by the sounds of the simulator because their limited experience with aircraft had not allowed for habituation to loud noises.

Results may have also differed because of the locations of the two studies. In Canada, the 15 male sheep observed were presumably on their summer range. If even slightly disturbed, the sheep could have moved away from the source of disturbance to another part of the range, a relatively large area of similar habitat. By contrast, sheep observed during the Marsh Fork study were at mineral lick, a specific, unique location restricted in size. As sheep presumably come to mineral licks because of physiological needs for certain substances, the incentive to stay at a lick may be great, in spite of disturbances in the vicinity.

Many aspects of sound disturbance were not examined during the study. The simulator experiment was conducted during midsummer at a relatively noncritical time of year; little is known about the effects of sound disturbance during other seasons. In winter when food is scarce and snow restricts movement, disturbance may have an important effect on survival. In spring, ewes with young lambs may be more sensitive to loud sounds.

The different reactions of individuals to sudden simulator sounds and the shifts in location of sheep at the licks during experimental Phase II suggest that individual sheep respond differently to disturbance. These individual reactions may be important. Sheep are extremely social animals. If one sheep bursts into panic flight, nearby animals usually run also. Thus, a relatively few individuals sensitive to disturbance could effect the population of the area.

Disturbance may not be overt. Subtle effects such as constant nervousness, slight disruptions of feeding and resting bouts, etc., are difficult to detect but may be important.

However, within the limits of the study, sheep showed no extreme response to the sounds of the simulator, suggesting that during midsummer, sheep may be able to adjust to certain levels of auditory disturbance.

SUMMARY

1. A study was conducted to determine the effects of the simulated sounds of a 20,000 horsepower gas compressor station on Dall sheep using mineral licks.

2. Observations of sheep at two mineral licks were made during two control phases when the sound simulator was turned off and during an experimental phase when the sound simulator was turned on.

3. The sound simulator was located about 1/4 mile from mineral lick L-4 and 3/4 mile from mineral lick L-18. Sheep at L-4 were subjected to sound ranging from 58 decibels to 73 decibels, while sheep at L-18 were exposed to sound levels too low to be detected with a decibel meter, although faintly audible to the human ear.

4. The sounds of the simulator had no depressing effect on numbers of sheep using mineral lick L-4. Sheep still came into the lick after the simulator was turned on. There was no statistically significant difference between the control and the experimental phases in the number of sheep-hours or the estimated number of individuals observed.

5. Simulator sounds did not prevent sheep from resting at

L-4. A greater percentage of resting sheep was observed at both licks during the experimental phase.

6. The length of time that individuals spent at L-4 was not decreased by the sounds of the simulator. Average times spent at the lick did not differ significantly between control and experimental phases. Observations made at L-18 were comparable to those made at L-4.

7. Sheep at L-4 spent less time in the part of the lick subjected to the highest sound levels during the experimental phase. A similar shift was observed at L-18 suggesting that individuals may have moved to locations where simulator sound levels were lower.

8. Sounds of the simulator did not prevent certain sex or age groups from using mineral lick L-4. All segments of the population (rams, ewes, and lambs) were present at both licks during control and experimental phases.

9. Simulator sounds apparently did not affect the distribution of sheep in the vicinity of the licks.

10. During 20 observations of sheep responding to aircraft, the animals generally showed strong reactions to low-flying helicopters coming within 150 yards but showed mild or no reactions to aircraft as far away as the simulator. Sheep using the mineral licks had been exposed

to large amounts of aircraft noise for at least 2 months prior to the onset of the experiment.

11. Sheep at mineral lick L-4 reacted mildly or not at all when the sounds of the simulator were suddenly turned on.

12. Limited observations of other birds and mammals in the study area suggest these species did not react strongly to simulator sounds. Red foxes may have avoided areas adjacent to the simulator.

13. Sheep subjected to aircraft noise may have become habituated to auditory disturbance in their environment and consequently showed no extreme response to the sounds of the simulator.

14. During midsummer sheep may be able to adjust to certain levels of auditory disturbance.

CONCLUSIONS AND RECOMMENDATIONS

The results of the experiment indicate that during midsummer Dall sheep using a mineral lick were not strongly disturbed by simulated compressor station sounds produced approximately 1/4 mile away which resulted in maximum sound pressure levels of 73 decibels at the lick. Lack of response may have been due to prior exposure to loud noises from aircraft. However, the sheep were not totally unresponsive to sounds in their environment. Some showed strong reactions to low-flying aircraft, indicating that habituation, if present, was only to auditory disturbance below a certain level. The magnitude of sound which could disturb sheep is not known.

Other aspects of a compressor station such as olfactory and visual factors were not examined in this experiment, but must be considered as possible sources of disturbance.

Caution must be used in selecting sites for compressor stations. Construction of a station as well as its operation and maintenance will involve extensive human impact in the station area. A variety of disturbances could result. Chronic exposure to disturbance or the compounding effects of disturbance and environmental stress during critical times of the year could have detrimental effects on the sheep population.

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APPENDIX

STATISTICAL ANALYSIS

Interpretation of the simulator experiment data was facilitated by statistical analysis of some measurements made of sheep numbers and activity.

Analysis of Variance

A one-way analysis of variance was used to test hypotheses concerning the mean number of sheep-hours and estimated number of individuals recorded at mineral lick L-4. This statistical tool computes the variation among the sample means and the variation within the samples as two comparable estimates of variance, a measure of difference among the means.

Certain assumptions must be made before this kind of analysis can be used: samples must be randomly chosen from populations having approximately normal distributions and equal variances. Moderate violations of the last two assumptions apparently change the results of analysis very little (Dixon and Massey, 1957, p.151).

Samples consisted of observations of sheep-hours and estimated numbers of individuals recorded during a given phase of the experiment. As observations were made during a series of days arbitrarily selected from all possible days of a lick use season, the samples were assumed to be random.

A total variation within a set of data may be due to actual differences among the sample means or may be due to chance differences within the samples.

As the number of observations within each sample was unequal, the following computing formulas were used to compute the total variation and its two components:

$$SS_T = \Sigma\ \Sigma\ x_{ij} - \frac{1}{N} \cdot T^2 \text{ (total variation)}$$

$$SS_A = \Sigma\ \frac{Ti^2}{ni} - \frac{1}{N} \cdot T^2 \text{ (variation among sample means)}$$

$$SS_W = S\ S_T - S\ S_A \text{ (variation within samples)}$$

where x_i donates a given observation (i.e. the number of sheep-hours of estimated individuals recorded on a given day), n denotes the number of observations within a given phase, N denotes the total number of observations in all phases, T_i denotes the total of all observations in a given phase, and T denotes the grand total of all observations.

Sheep Numbers at L-4

Three null hypotheses related to sheep numbers at L-4 were tested:

1. mean sheep-hours were the same during the three phases of the experiment;

2. mean estimated minimum numbers of individuals were the same during all three phases of the experiment; and

3. mean estimated maximum numbers of individuals were the same during all three phases of the experiment.

Data from Table 5 were used in the analyses, after data from 16 July and 21 July had been combined.

The sums of squares were arranged in analysis of variance tables:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
		Numbers of Sheep-Hours		
Among	1	2014.6	2014.6	.61
Within	12	39836.1	3319.6	
Total	13	41850.7		
		Estimated Minimum Numbers of Individuals		
Among	1	807.0	807.0	2.8
Within	12	3419.4	284.9	
Total	13	4226.4		
		Estimated Maximum Numbers of Individuals		
Among	1	1057.4	1057.4	2.5
Within	12	5112.0	426.0	
Total	13	6169.4		

From a table of F distribution at 1 and 12 degrees of freedom, the value of F at the 0.05 level of significance is 4.75

(Freund, 1967, p.387). The calculated F statistic for the null hypothesis that the mean number of sheep-hours were the same during all three phases of the experiment was 0.61. This value was considerably less than the table value 4.75; therefore, the null hypothesis cannot be rejected.

The calculated values of F for null hypotheses stating that the means of the estimated minimum and maximum numbers of individuals were the same for all three phases were also less than the table value of F. These null hypotheses also cannot be rejected.

Variation among the sample means was less than the chance variation within the samples for these three sets of data. If differences in the mean number of sheep-hours or estimated numbers of individuals did occur, they were not greater than day-to-day variability at L-4.

Sheep Numbers at L-18

A similar statistical analysis was used to examine data on sheep numbers from mineral lick L-18. Three null hypotheses were tested:

1. mean sheep hours were the same during experimental phase II and control phase III;

2. mean estimated minimum numbers of individuals were the same

during experimental phase II and control phase III; and

3. mean estimated maximum numbers of individuals were the same during experimental phase II and control phase III.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
		Number of Sheep-Hours		
Among	1	11.0	11.0	0.01
Within	7	5157.9	736.8	
Total	8	5168.9		
		Estimated Minimum Number of Individuals		
Among	1	0.4	.4	0.01
Within	7	277.6	39.7	
Total	8	278.0		
		Estimated Maximum Number of Individuals		
Among	1	8.4	8.4	0.12
Within	7	489.6	69.9	
Total	8	498.0		

From a table of F distribution, at 1 and 7 degrees of freedom, the value of F at the 0.05 level of significance is 5.59 (Freund, 1967 p.387). As the calculated values of F were much less than this value, the three null hypotheses cannot be rejected. The variation among the sample means was much less than variation within the samples. If differences in the mean number of sheep hours or estimated numbers of individuals did occur between the experimental and control phases of the experiment, they were not greater than day to day variability at L-18.

Number of Hours Individuals Stayed at L-4

Data concerning the mean number of hours that sheep stayed at mineral lick L-4 were also subjected to a one way analysis of variance. The null hypothesis tested stated: the mean numbers of hours that individuals stayed at mineral lick L-4 did not differ during each phase of the experiment. Figures from Table 7 were used in the computations.

The sum of squares were arranged in an analysis of variance table:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Among	2	0.2	0.1	0.02
Within	19	96.0	5.0	
Total	21	96.2		

The table value of F at 2 and 19 degrees of freedom and a 0.05 level of significance is 3.52 (Freund, 1967 p.387). Because the calculated value of 0.02 is much less than 3.52, the null hypothesis cannot be rejected. There was no significant difference in the length of time individuals stayed at L-4 during the three phases of the experiment as there was more variation within a phase than among phases.

Numbers of Hours Individuals Stayed at L-18

A similar one-way analysis of variance examined the following null hypothesis: the mean numbers of hours that individuals stayed at mineral lick L-18 did not differ during experimental Phase II and control Phase III. Data used in the calculations were taken from Table 12.

The analysis of variance table was as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Among	1	1.5	1.5	0.62
Within	10	23.7	2.4	
Total	11	25.2		

The table value for F at 1 and 11 degrees of freedom and at the 0.05 level of significance is 4.84 (Freund, 1967 p.387). The computed value of F is much less than 4.84. The null hypothesis cannot be rejected. There is no significant difference among the mean number of hours individuals spent at mineral lick L-18 during experimental Phase II and control Phase III as there was more variation within a phase than between the phases.

A Comparison of Numbers of Hours Individuals Stayed at L-4 and L -18

The number of hours individuals spent at mineral lick L-4 and mineral lick L-18 were compared by using a one-way analysis of variance to test the null hypothesis: the mean number of hours individuals spent at L-4 and L-18 did not differ. All observations from a lick were combined. Figures from Table 7 and Table 12 were used in the calculations.

The sum of squares were arranged in an analysis of variance table:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Among	1	3.6	3.6	0.95
Within	32	121.4	3.8	
Total	33	125.0		

From a table of F distribution at 1 and 32 degrees of freedom, the value of F at the 0.05 level of significance is 4.17 (Freund, 1967, p.387). As the calculated value of F is less than 4.17, the null hypothesis cannot be rejected. There was no significant difference between the length of time individuals stayed at L-4 and L-18 as there was more variation at a given lick than between licks.

χ^2 Test

Location of Sheep at L-4

Data concerning the location of sheep at mineral licks were subjected to a different kind of statistical analysis.

As the data consisted of frequencies in discrete categories, i.e. numbers of sheep-hours recorded at one of three locations, a χ^2 test was used to determine the significance of differences between control and experimental phases, assuming the phases were independent. This test examines differences between observed frequencies and expected frequencies.

The null hypothesis was that sheep-hour frequencies observed at the north, mid and south licks did not differ during experimental Phase II and control Phase III. It was tested using the following formula:

$$\chi^2 = \Sigma \; \Sigma \; \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where O_{ij} denotes the number of sheep-hours observed in a given location during a given phase, and E_{ij} denotes the number of sheep-hours expected in a given location during a given phase.

The calculated value of χ^2 is compared to a χ^2 value taken from a χ^2 distribution table for a particular level of significance (α) and for degrees of freedom equal to $(k-1)(r-1)$, where r equals the number of locations on the lick, and k equals the number of phases being compared. If the calculated value of χ^2 is equal to or greater than the appropriate table value, the null hypothesis may be rejected.

For this null hypothesis, observed frequencies were numbers of sheep-hours recorded during experimental phase II and control phase III at L-4 lick locations (Table 8). Expected frequencies were calculated by multiplying all sheep-hours observed at a given location by all sheep-hours recorded during a given phase and dividing the result by the total sum of all sheep hours observed:

	Phase II		Phase III	
	Observed	Expected	Observed	Expected
North Lick	33.5	23.5	23.0	33.0
Mid-Lick	88.0	115.4	189.0	161.6
South Lick	42.5	25.0	17.5	35.0

The calculated chi square value for the above data is 39.45. At a 0.01 level of significance and 2 degrees of freedom, the value for chi square is 9.21. As the calculated value of chi square greatly exceeds the table value, the null hypothesis can be rejected. There was a significant difference between experimental phase II and control phase III in the sheep-hour frequencies at the north, mid and south lick areas of mineral lick L-4.

Location of Sheep at L-18

A similar analysis using the chi square test examined the null hypothesis that sheep-hour frequencies observed at the west, mid and east lick areas of mineral lick L-18 did not differ during experimental phase II and control phase III.

Observed frequencies were numbers of sheep-hours recorded during experimental phase II and control phase III at L-18 lick locations (Table 13). Expected frequencies were calculated using the method described previously:

	Phase II		Phase III	
	Observed	Expected	Observed	Expected
East Lick	25.0	22.1	27.0	29.9
Mid-Lick	40.0	24.8	18.5	33.7
West Lick	34.5	52.6	89.5	71.4

The calculated chi square value for the above data is 27.64. As this greatly exceeds the table value of 9.21 at a 0.01 level of significance and 2 degrees of freedom, the null hypothesis can be rejected. There was a significant difference between experimental phase II and control phase III in the sheep-hour frequencies observed at the west, mid and east lick areas of mineral lick L-18.