Ecology of reintroduced Rocky Mountain bighorn sheep following two transplants in the southern Madison Range, Montana
by Johnna Lynn Roy

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Rocky Mountain bighorn sheep were monitored from January 1988 through July 1990 during the first 2.5 years following their release into the Southern Madison Range of southwestern Montana. Specific objectives were to document survival, productivity, movements, habitat use and range establishment, and possible limiting factors of transplanted sheep. Data on remnant native sheep herds were also collected.

Two groups of sheep were transplanted from Thompson Falls and Anaconda, Montana during the winters of 1988 (19 sheep) and 1989 (23 sheep), respectively. Twenty-six sheep were radio-collared and released on 2 different historic winter ranges 16 km apart in the Hilgard Peaks. Remnant native herds were present at both release sites.

Two native ewes were darted and radio-collared in 1989.

Blood samples were within normal ranges of cell counts and serum composition for Montana bighorns, and fecal samples indicated presence of lungworm (Protostrongylus sp.) infection in 1988 transplants and Hilgard native sheep (x = 327 and 8 larvae per gram, respectively). Survival through June 1990 for the original transplanted sheep was 100% and 69% for the 1988 and 1989 release groups, respectively. The transplant population increased to 65 (55% increase) in 2.5 years. Lamb production was moderately high and mortality was low. Lamb:ewe ratios were 23:100 (1988), 67:100 (1989), and 39:100 (1990) for the 1988 transplant group and 61:100 (1989) and 47:100 (1990) for the 1989 group. Native sheep bands had slightly higher ratios over the same interval.

Both transplant groups exhibited a gradual range expansion. Seasonal migrations were characterized by an elevational drift from winter range release sites to adjacent alpine ridges. Movements from summer to winter ranges were common during the summer. Cliffs adjacent to winter ranges (within 2 km) were used for lambing. Exploratory movements up to 7 km were made mainly by rams. One 1989 transplant ewe moved 12 km after release and permanently joined the 1988 transplant band. Transplant rams remained with ewe groups throughout the year. Five distinct native sheep bands were recognized. Bands utilized the 2 common historic winter ranges, but migration and selection of high elevation summer ranges was independent.

Limiting factors identified were interspecific competition with other sympatric ungulates, and intraspecific competition for limited winter range resources.

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

June 1992

APPROVAL

of a thesis submitted by

Johnna Lynn Roy

This thesis has been read by each member of the graduate committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGMENTS

A special thanks is due my major professor, Dr. Lynn Irby, for his guidance and patience throughout the study and manuscript preparation. Drs. Harold Picton, John Taylor, and Calvin Kaya critically reviewed the manuscript and offered helpful advice. Thanks to Dr. David Worley for his assistance and use of the Veterinary Research Lab.

Funding for this project was provided by the Foundation for North American Wild Sheep, the Montana Department of Fish, Wildlife, and Parks (MDFWP), and the U.S. Forest Service. I wish to thank Graham Taylor and the late Arnie Foss for their help in getting the project underway, Merritt Pride for his commitment to bighorn sheep conservation, MDFWP personnel Kurt Alt, Harry Whitney, Fred King, and Mike Ross for logistical support and assisting with field work, Claude Coffin, Dan Trochta, and the Forest Service in West Yellowstone.

Special appreciation goes to the landowners of the Madison Valley for granting access on their land, especially the Sun Ranch. My heartfelt thanks go to Dale and Virginia Black for their hospitality and friendship, to Jane and Bud Neis for their observations, to Dave and Roger Stradley, patient and skilled pilots, and to Don Polanski for his continuous support and patience.

TABLE OF CONTENTS

TABLE OF CONTENTS--(Continued)

LIST OF TABLES

LIST OF TABLES--(Continued)

LIST OF TABLES--(Continued)

LIST OF FIGURES

ABSTRACT

Rocky Mountain bighorn sheep were monitored from January 1988 through July 1990 during the first 2.5 years following their release into the Southern Madison Range of southwestern Montana. Specific objectives were to document survival, productivity, movements, habitat use and range establishment, and possible limiting factors of transplanted sheep. Data on remnant native sheep herds were also collected.

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INTRODUCTION

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) are indigenous to the Madison Mountains of southwestern Montana. The Hilgard Peaks and Henrys Lake Mountains of the southern Madison Range have historically supported a small, huntable population of sheep. Buechner (1960) summarized the scant data available and reported that approximately 25 sheep were observed near Hebgen Dam in spring 1943 and 18 were counted near Moose Creek in February 1955 by the Montana Fish and Game Department. He noted the Hilgard population remained small in years prior to 1960 and suggested that summer cattle grazing of bighorn winter range could have been limiting sheep numbers.

Annual surveys conducted by the Montana Department of Fish, Wildlife and Parks (MDFWP) during 1966-1981 indicated a stable population with minimum estimates of 51-61 sheep. A December 1982 census of traditional winter ranges produced 23 bighorns, whereas 59 were counted in December 1981. By 1987, only 5 sheep were observed where more than 50 had wintered less than a decade before. Reasons for the decline are unknown, but possible contributing factors include competition with other native ungulate species and/or domestic livestock, habitat deterioration, excessive mortality due to disease, hunting or predation, and catastrophic accident due to extreme weather (Graham Taylor, pers. comm., January 1988).

MDFWP initiated a program to restore Hilgard bighorn population levels in 1984. Agreements with landowners were obtained to increase access for hunters near traditional sheep range so that harvest of 2 potential competitors, elk (Cervus elaphus nelsoni) and mountain goats (Oreamnos americanus), could be increased. This hunting district was closed to sheep harvest in 1987.

Transplanting of bighorn sheep is a useful management tool to maintain habitat and population quality for expanding herds and to repopulate historical ranges or extend existing bighorn ranges. Introduced herds have exhibited a range of responses from failure to successful establishment (Couey and Schallenberger 1971). Wishart (1975) concluded that the weakest aspect of trapping and transplanting programs has been the monitoring and evaluation of success. A better understanding of the ecology of introduced herds should improve the ability of wildlife managers to effect successful transplants.

MDFWP transplanted 42 sheep into the southern Madison Range in January 1988 (19 sheep) and January-February 1989 (23 sheep) to augment the existing remnant native population. This project was initiated to monitor the status of the transplanted sheep during the first 2 years following release and to investigate factors which could have caused the decline of the native Hilgard bighorns (and thus jeopardize the success of the transplants). The objectives were to (1) document survival, productivity, movements, and habitat use of transplanted sheep, (2) monitor the influence of actions implemented by MDFWP to reduce hypothesized limiting factors to Hilgard sheep, and (3) recommend management actions to insure a huntable population of bighorn sheep in the southern Madison Range. Field work was conducted January 1988 through July 1990.

STUDY AREA

Location and Physiography

The study area was located in the southern Madison Range and northern Henrys Lake Mountains of Madison and Gallatin counties in southwestern Montana. The 407 square kilometer area is approximately 30 km northwest of West Yellowstone, Montana (Figure 1). The area is bordered to the north by the Wolf Creek and Taylor Fork drainages, to the south by the Continental Divide, on the west by the Madison Valley, and by the Beaver Creek drainage to the east (Figure 2).

The Hilgard Peaks portion (290 km^2) of the study area has mixed ownership. Approximately 88% is in the Taylor-Hilgard Unit of the Lee Metcalf Wilderness, administered by the Gallatin and Beaverhead National Forests. The remaining 12% is located in foothills on private (10%), state (1%), and Bureau of Land Management (1%) land. The southern portion of the study area in the Henrys Lake Mountains (117 km^2) is administered by the Gallatin National Forest (Figure 2).

Lowest elevations (1890 meters above sea level) occur along the Madison River. Highest elevations occur along

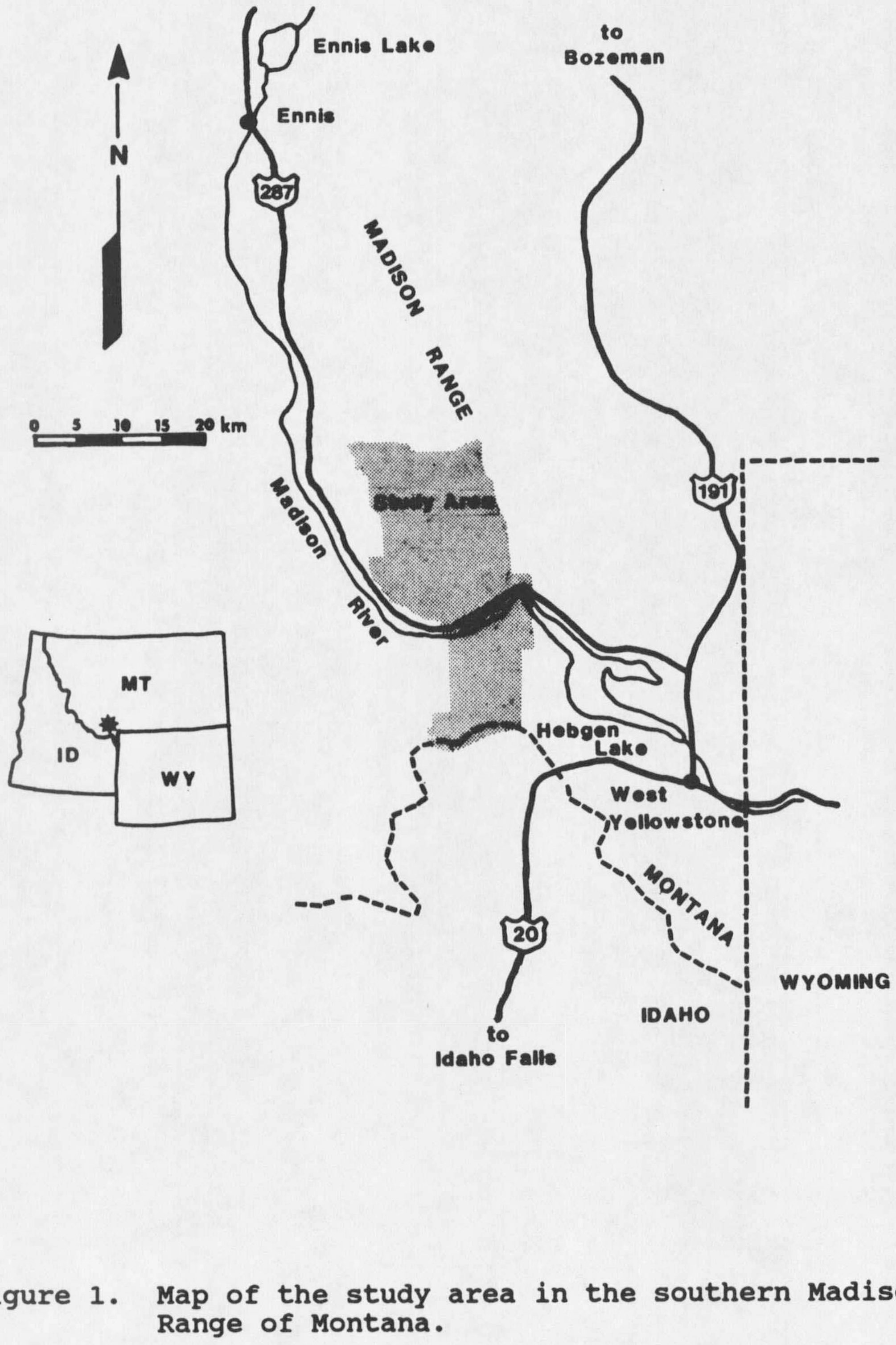


Figure 1. Map of the study area in the southern Madison Range of Montana.

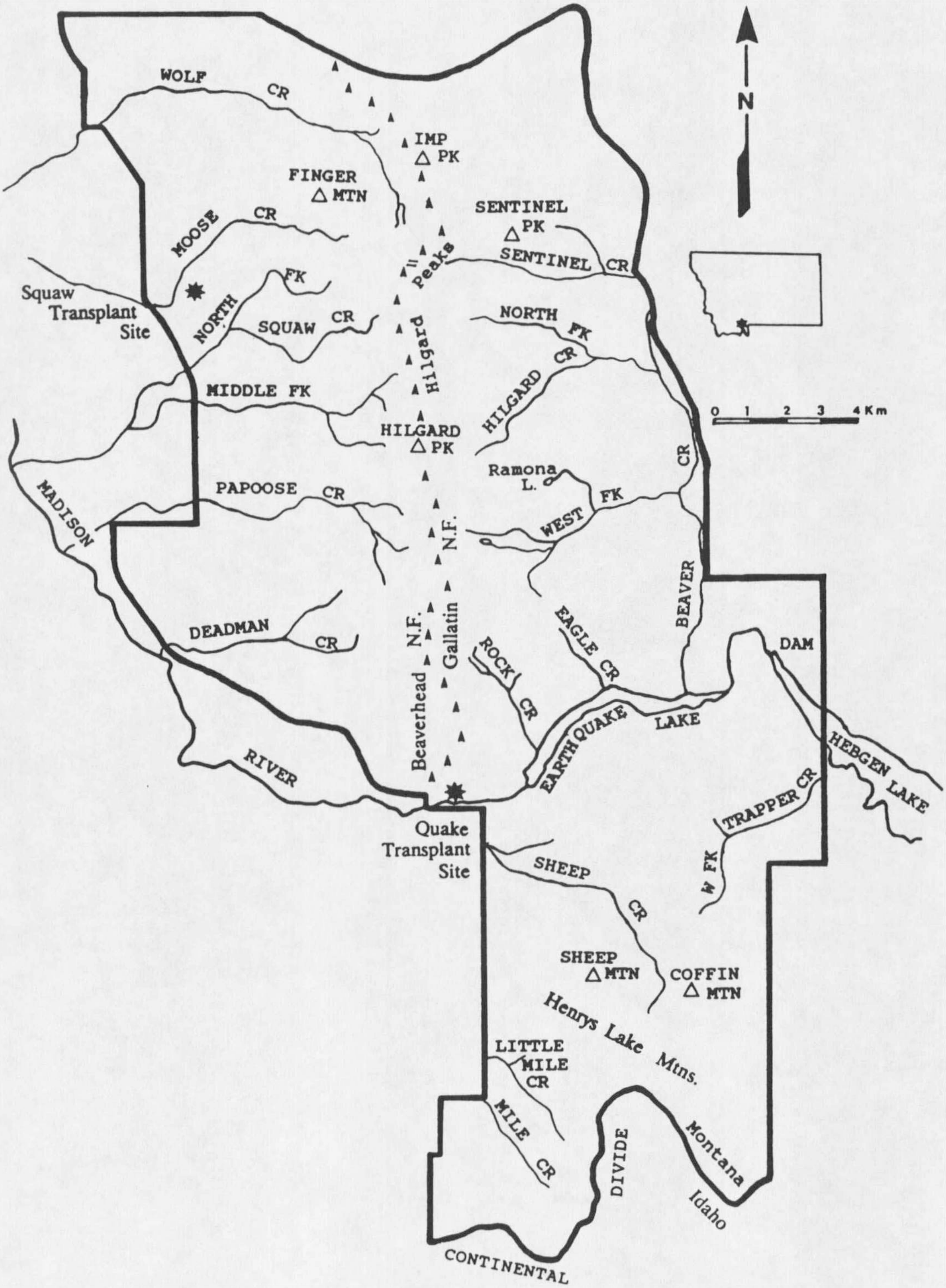


Figure 2. Map of the study area showing major features and transplant release sites.

the rugged crest of the Madison Range; 3449 m at the summit of Hilgard Peak to the north and 3233 m (unnamed peak) to the south in the Henrys Lake Mountains.

Geology and Soils

The Madison Range was uplifted by tensional block faulting which began during the Tertiary Period and continues along active faults in the western and southern edges of the range (Alt and Hyndman 1986, Witkind et al. 1964). The Taylor Peaks-Hilgard-Sheep Mountain block consists mainly of Precambrian crystalline basement rock that was formed approximately 2.7 billion years ago during the Archaen era. Metamorphic gneiss, schist, quartzite and marble that formed from igneous and sedimentary parent rocks are common (Taylor and Ashley 1986, Erslev 1983).

The southern Madison Range exhibits the characteristic features of glaciated mountain terrain with rocky peaks, cirque basins, rock glaciers, and trough valleys. The terrain is deeply dissected by steep slopes with bedrock outcrops, talus, and avalanche chutes common (Davis and Shovic 1984, Richmond 1964). Ridges terminate in precipitous rounded foothills where they meet the Madison Valley on the west side of the range.

Where soils have developed, they are coarse to medium textured of metamorphic parent material. Soils are predominantly Cryochrepts, Cryorthents, or Cryumbrepts and are shallow to deep, well drained, and moderately acidic (Davis and Shovic 1984, Veseth and Montagne 1980).

Climate and Weather

The study area has a typical montane climate with short, cool summers and long, cold winters. Normal annual precipitation (averaged from 1941-1970) ranges from 50 cm to 150 cm dependent on elevation (U.S. Dept. Agric. 1980). Normal annual snowfall (averaged from 1922-1975) is 510 cm to 760 cm (Farnes and Shafer 1975).

Wind is an important factor in the Madison Range. Strong, persistent south winds that funnel up the valley affect snow deposition patterns on foothill winter ranges. Ridges are blown bare exposing forage, especially on the Squaw Creek winter range.

Flora and Fauna

Vegetation of the study area varies by elevation and aspect. The adjacent Madison Valley supports typical intermountain grassland-sagebrush vegetation on glacial moraine hummocks and benches, with mesic sites along drainages and seeps supporting timber. Southern aspects of foothills are a mosaic of mountain grassland and mountain shrubland at lower elevations to alpine vegetation at higher elevations.

Common graminoids include Idaho fescue (Festuca idahoensis), bluebunch wheatgrass (Agropyron spicatum), tufted hairgrass (Deschampsia caespitosa), bluegrass (Poa spp.), needlegrass (Stipa spp.), danthonia (Danthonia spp.), and sedges (Carex spp.). Common forbs and shrubs include western yarrow (Achillea lanulosa), mountain pussytoes (Antennaria parvifolia), aster (Aster spp.), alpine milkvetch (Astralagus alpinus), fleabane (Erigeron spp.), sandwort (Arenaria spp.), Hood's phlox (Phlox hoodii), eriogonum (Eriogonum spp.), fringed sagewort (Artemisia frigida), and cinquefoil (Potentilla spp.). Sagebrush (Artemisia tridentata var. wyomingensis) patches are found at lower elevations and in draws that accumulate snow.

The northern aspects of foothills are generally forested by dense to scattered stands of Douglas fir (Pseudotsuga menziesii) or lodgepole pine (Pinus flexilis) with bunchgrass and shrub understories. The main Quake Lake winter range is an exception with an open Douglas fir stand on a south aspect.

Higher elevation ridges, cirque basins, and peaks comprising sheep summer range are characterized by open grown to dense stunted forests of subalpine fir (Abies lasiocarpa), Engelmann spruce (Picea engelmanii), limber pine (Pinus flexilis), and whitebark pine (Pinus albicaulis); krummholz; and alpine vegetation. Forest understories commonly contain grouse whortleberry (*Vaccinium scoparium*), heartleaf arnica (*Arnica cordifolia*), sedges, and other forbs. Alpine meadows of cirque basins contain tufted hairgrass, Idaho fescue, sedges and numerous forbs. Harsh sites on ridges and peaks support tundra type vegetation of forbs, sedges, mosses and lichens (Pfister et al. 1977, Mueggler and Stewart 1980).

Ungulates that were observed on the study area include elk, mountain goat, mule deer (*Odocoileus hemionus*), and moose (*Alces alces*). Carnivores that inhabit the area included black bear (*Ursus americana*), mountain lion (*Felis concolor*), coyote (*Canis latrans*), and bobcat (*Felis rufus*). Golden eagles (*Aquila chrysaetos*) and numerous buteos are also common.

METHODS

Sheep Capture, Marking, and Transplant

The first transplant of 19 bighorn sheep were released at the Hilgard Squaw Creek winter range on 29 January 1988 (Figure 2). Sheep were captured in a corral trap baited with alfalfa hay near Thompson Falls, Montana. The transplanted group consisted of 2 rams (1½ and 2½ years of age), 11 ewes (ages 1½ to approximately 6½), and 6 lambs (4 males and 2 females). Animals were aged by horn annuli and dentition (Geist 1966, Lawson and Johnson 1982), blood and fecal samples were taken, and injections of Combiotic were administered. Adults were fitted with individually marked, molded polyvinyl chloride (PVC) collars containing AVM (AVM Instrument Co., Ltd., Livermore, CA) radio transmitters (Pederson 1977). Lambs were tagged in both ears with plastic color-coded and individually marked eartags. All animals were fitted with MDFWP numbered aluminum eartags. All 13 adults were radio-collared, and the 6 lambs were marked with color-coded livestock eartags (Appendix, Table 13). Sheep were captured, transported by horse trailer, and released at the transplant site over a period of approximately 55 hours.

The second transplant of 23 sheep were released at the Hilgard Earthquake (Quake) Lake winter range in 2 phases in January and February, 1989 (Figure 2). Five sheep captured near Thompson Falls by the same method, including 1 ram (age 3½), 2 ewes (ages 4½ and 2½), and 2 lambs (1 male, 1 female), were released on 13 January. An additional 18 sheep were captured on the Lost Creek (LC) winter range near Anaconda, Montana by a MDFWP helicopter drive-netting operation (Beasom et al. 1980, Jessup et al. 1984) and released at the Quake Lake transplant site on 9 February. This group consisted of 1 ram (age 1½), 14 ewes (ages 1½ to 5½) and 3 lambs (1 male, 2 female). The same procedures were followed, except all sheep were drenched with Fenbendazole to treat for lungworm (<u>Protostrongylus</u> <u>sp</u>.) infection (Huschle and Worley 1986, Anderson 1971). Thirteen adult sheep were radio-collared, 5 adults were collared with individually marked blue plastic Ritchey neckbands, and 5 lambs were marked with livestock eartags (Appendix, Table 14). Time elapsed between capture and release was approximately 24 hours.

Two native Hilgard sheep were darted on historic winter range in March 1989. Telazol was used with limited success to immobilize the ewes. Attempts to immobilize and collar native rams failed due to insufficient dosage information for this new drug. The natives were radio-collared, ear-tagged, treated with Combiotic, and blood and fecal samples were taken for analyses (Appendix, Table 15).

Blood samples were analyzed at the Montana State University (MSU) Veterinary Research Lab for blood chemistry and serum antibody titers. The University of Idaho performed Pregnancy Specific Protein B (PSPB) assays of blood samples to determine pregnancy (Sasser et al. 1986). Fecal samples were analyzed at MSU for lungworm loads (larvae per gram) using the Baermann technique (Baermann 1917).

Seasonal Distribution, Movements and Habitat Use

Movements and seasonal habitat use were determined from aerial and ground relocations of radio-collared and marked sheep. Aerial relocations were made in a Piper Super Cub equipped with a belly-mounted, directional 3-element Yagi antenna. Flights were scheduled at monthly intervals from December through May, and biweekly from June through September. Location flights were not made during late October through November to avoid disturbing hunters. Storms and frequent high winds in the southern Madison Range reduced planned sampling intensity. Aerial relocations without visual confirmation were assumed to be accurate to within a 5.5 hectare circle (Denton 1973).

Ground relocations for transplanted sheep were made with an AVM LA-12 receiver and a hand-held 2-element Yagi antenna. Winter relocations were made from a vehicle or on foot. Three to 6-day backpacking trips were made to relocate sheep on summer range. Triangulation was used to pinpoint locations whenever possible, but rugged topography often precluded it. Most relocations were visually confirmed by searching the indicated area with a 15-60x spotting scope.

Ground and aerial searches (Thomas 1957) were conducted to locate remnant bands of native Hilgard sheep on historic winter and summer ranges. Natives were classified as ewe, lamb, or ram; and rams classified by the degree of horn curl (<1/4, 1/4, 1/2, 3/4, 3/4+) (Geist 1971, MDFWP 1980). When possible, ram horn annuli were counted to estimate age (Geist 1966). Records of distinguishing characteristics (broomed or cracked horns, scars, etc.) were kept to aid in tracking movements and survival of unmarked natives.

Locations of all sheep observed during flights and ground censuses were plotted on 1:24,000 USGS quadrangle maps. Universal Transverse Mercator (UTM) coordinates, elevation, aspect, terrain type, and cover type were recorded. Additional data collected during 1-10 hour ground observation periods included group classification and identification (if marked), movements, activity, time of day, and weather.

Habitat use was characterized by 4 parameters: cover type, terrain type, elevation, and aspect. Cover type classifications included timber-closed canopy (>30% canopy closure), timber-open canopy (<30% canopy closure), grass-forb, shrub, rock-bare ground. Terrain type categories included cliff, sidehill, ridge, rock outcrop, broken (interspersed gullies, ridges, and rock outcrops), and avalanche chute. Elevation was broken into 150-m classes ranging from 1831 m to 3353 m. Aspect was categorized as N, NE, E, SE, S, SW, W, NW.

Observations of groups of sheep were treated as single data points, and sheep more than 250 m from other sheep were recorded as separate data points. Data from daily ground observations period (1-10 h) were randomly sampled (by time) to produce one relocation per individual sheep group per day.

Habitat use data were summarized by season and by sheep group. Seasons were defined as follows: winter = December 1-May 31, summer = June 1-November 30. The four major groups of sheep included transplanted and native sheep that wintered at Squaw Creek and transplanted and native sheep that wintered at Quake Lake. Percentages of relocations in various habitat categories for each group by season were calculated. A Chi-square analysis was used to determine whether significant differences existed in habitat use (cover type and terrain type) between the sheep groups on summer and winter ranges ($P<0.05$).

Survival and Population Dynamics

Survival of transplanted sheep was determined through ground observations of marked sheep. If individual sheep were not observed for an extended period, aerial relocation and/or ground searches were conducted. Carcasses were examined to determine cause of death.

Lamb production counts began in mid-May and continued until all marked ewes were observed (with or without lambs) and all lambs counted. Ground observations in summer were used to monitor survival of lambs. Classification counts on summer and winter ranges provided the best data for survival and population dynamics estimates.

Survival and productivity data for remnant native bands were more difficult to obtain. Lamb counts were made when bands were located on summer range, but only winter range classification counts provided consistent data. These classification counts were repeated throughout the winter and provided the basis of population dynamics estimates for the native Hilgard sheep bands.

Factors Influencing Survival

Vegetation production and use at the Squaw Creek winter range was determined by clipping 20x50 cm plots inside and outside 3 forage protection cages placed on the winter range prior to the 1988 transplant. Clipping was done in October (post-growing season but prior to arrival of winter sheep and other ungulates) and April (pre-growing season). Differences were tested using analysis of variance and t-tests.

Use of primary winter range by other ungulates was determined by their distribution during observation periods, observation of other species during radio relocation flights, track counts on winter range, and notes on elk and cattle feces distribution on winter ranges. Levels of predator activity and human disturbance were noted during observation periods.

MDFWP yearly census records were obtained for elk and mountain goat populations in the Hilgard study area. Records analyzed dated back to 1977, before the decline of the native sheep population. Historical grazing records were obtained for 2 Beaverhead National Forest cattle and horse allotments that potentially impact sheep winter range.

Weather data from 4 weather stations (National Oceanic and Atmospheric Association and U.S. Soil Conservation Service) near the study area were summarized from 1978 through completion of the study. Data from four weather stations were used to characterize the weather variation observed. Snow depths increased from north to south and from low to high elevation on the study area. The Ennis station is located approximately 43 km north of the Squaw Creek winter range at 1510 m elevation. The Hebgen Dam station is located 10 km east of the Quake Lake winter range at 1978 km. Two high elevation, automated snow pillow sites are located at Taylor Peak and Carrot Basin (2519 m and 2743 m, respectively) at the north end of the study area.

RESULTS

Sheep Capture, Marking, and Transplant

Transplant groups were predominantly adult ewes (57.9% at Squaw Creek, and 69.6% at Quake Lake) to maximize breeding potential. Adult rams (>1 yr. old) constituted 10.5% of the Squaw group, and 8.7% of the Quake group (Table 1). Data for individual sheep transplanted are in Tables 13 and 14 (Appendix).

Table 1. Classification summary of transplanted sheep that were released at Squaw Creek winter range (SCWR) and Quake Lake winter range (QLWR).

Transplant Location	Total Sheep	Rams No.	Rams %	Rams $\bar{x}$ Age	Ewes No.	Ewes %	Ewes $\bar{x}$ Age	Lambs Male No.	Lambs Male %	Lambs Female No.	Lambs Female %	Pregnancy Rate %
SCWR	19	2	10.5	2.0	11	57.9	4.1[a]	4	21.0	2	10.5	100[b]
QLWR	23	2	8.7	2.5	16	69.6	3.3	2	8.7	3	13.0	93

[a] 3 ewes not aged, not included in calculation.

[b] Blood samples not obtained from 4 sheep; 100% of 7 samples obtained tested positive (Appendix, Table 13).

Blood samples were obtained from 41 captured sheep (Thompson Falls, Lost Creek, and Quake Lake natives) to provide information on animal health. Biochemical and complete blood count (CBC) analyses indicated that blood composition, cell volumes, and ion levels were within the normal range for bighorns in Montana (Dan Palmisciano, pers. comm., June 1988). Table 16 (Appendix) provides blood analysis data from the Cinnabar and Rock Creek sheep herds for comparison with the values obtained in this study.

Blood serum antibody tests for brucellosis, bluetongue, leptospirosis, and anaplasmosis were performed to indicate past exposure to disease. Results were negative for brucellosis and bluetongue in all samples. Transplant sheep from Thompson Falls in 1988 tested 14.3% positive for anaplasmosis (2 ewes). All (N=5) of the 1989 TF blood samples indicated previous exposure to anaplasmosis, 80% tested positive and 20% were rated "suspect." Three Lost Creek sheep (15%) had a "suspect" test rating in 1989 (Appendix, Tables 17, 18).

Analysis of 35 fecal samples from Thompson Falls sheep, 15 samples from Lost Creek sheep, and 3 samples from Hilgard natives resulted in mean lungworm larval outputs of 326.9, 0, and 8.1 larvae per gram, respectively (Table 2). Fecal lungworm larvae counts for Thompson Falls sheep were above levels measured from 1970-1975 and 1981-1982 but were not indicative of severe lungworm infection (Dr. David Worley, pers. comm., May 1990).

In 1988, 100% of the Thompson Falls sheep sampled were infected with lungworm, compared to 88.8% in 1989. Fecal

Table 2. Frequency and intensity of lungworm infection in sheep transplanted from Thompson Falls and Lost Creek to the Hilgards, and in Hilgard natives. Baseline data from selected Montana sheep herds for comparison.

Sheep Population and Year Sampled	Sample Size (N)	Percent Infected (%)	Larvae Per Gram $\bar{x}$	Larvae Per Gram Range	% of Counts >100 LPG
Hilgard Transplant Data					
Thompson Falls 1988	17	100.0	334.1	(74.3-903.5)	82.3
Thompson Falls 1989[a]	18	88.8	319.7	(0-975)	61.1
Lost Creek 1989	15	0[b]	0	0	0
Hilgard Natives 1989	3	66.0	8.1	(0-24.2)	0
Historical Data[c]					
Thompson River 1970-75	200	85.0	33.0	(0-1038)	8.0
1981-82	101	77.5	85.1		4.9
Sun River 1970-75	104	90.0	37.2	(0-334)	13.3
1984	9	55.0	9.0		0
Ural-Tweed 1970-75	9	83.0	5.0	(0-47)	0
1985-87	216	83.6	27.2		5.0

[a] Data pooled from 19 sheep trapped 1-12-89 near Thompson Falls. Washington State University Veterinary Pathology Lab provided fecal analysis data on 14 sheep transplanted to Washington.

[b] Fecal samples frozen prior to Baermann analysis - data suspect.

[c] Data from Worley et al. (1976, 1988).

analysis for Lost Creek transplants showed no lungworm larvae. Hilgard natives had a 66% infection rate in 1989.

Survival and Population Dynamics

Transplanted Sheep Bands

Survival of the two transplant groups (Squaw Creek 1988 and Quake Lake 1989) during the winters following release varied significantly. One hundred percent of the Squaw transplants survived their first winter, whereas 74% of the Quake transplants survived winter 1989. Winter mortality following the 1989 transplant consisted of 3 adult sheep from Thompson Falls (1 male, 2 female) and 3 ewes from Lost Creek (2 adult, 1 yearling) (Appendix, Table 14).

A probable causative factor of the differential survival rates was winter severity. Annual precipitation was below normal and mean annual temperatures were above normal during the study. Annual weather summary data indicate that 1988 was warmer than normal by 1.1°C to 1.4°C (Ennis and Hebgen Dam weather stations, respectively) and dryer than normal by 1.42 cm to 27.0 cm. Annual summaries indicate 1989 was cooler and wetter than 1988 (Table 3). Specifically, the winter months following the 1988 transplant were all well above normal temperature and generally below normal precipitation levels. However, February 1989 was 8.5°C to 4.4°C (Ennis and Hebgen Dam)

Table 3. Annual summaries of mean temperature (°C), total precipitation (cm) and total snowfall (cm), and departures from normal for 4 weather stations near the Hilgard study area (1988-1990).[a]

		Temperature (°C)		Precipitation (cm)		Snowfall (cm)
Year	Station	Mean	Depart.	Total	Depart.	Total
1988	E[b]	7.5	+1.1	29.08	-1.42	[c]
	HD	3.6	+1.4	47.60	-27.00	467.36
	TP	0.3		59.43		472.40[d]
	CB	0.21		83.57		688.40[d]
1989	E	6.2	-0.2	32.13	+1.63	
	HD	2.3	+0.1	65.48	-9.12	541.02
	TP	-0.8		72.64		419.10
	CB	-1.13		104.14		619.70
1990	E	6.9	+0.5	30.15	-0.36	
	HD	2.7	+0.4	56.34	-18.26	409.91
	TP	-0.4		78.75		439.40
	CB	-1.26		98.04		568.90

[a] Data from the National Oceanic and Atmospheric Administration (NOAA) 1988-1990 (E and HD). Data from the Soil Conservation Service Snow Survey Unit, Bozeman, MT 1988-1990 (TP and CB).

[b] E = Ennis; HD = Hebgen Dam; TP = Taylor Peaks; CB = Carrot Basin.

[c] Data not available.

[d] Taylor Peaks and Carrot Basin are automated Snow Pillows, snowfall data are approximate.

below normal temperature, and March precipitation was 3.63 cm above normal (Hebgen Dam) (Appendix, Table 20).

Of the original transplanted sheep that survived their first winter, 100% of the Squaw band (19) were still alive at the completion of the study (July 1990). After the initial high winter mortality, the Quake band had a 94% survival rate through July 1990 (one radio-collared adult ewe was killed on Highway 287 in December 1989). All of the sheep transplanted as lambs in both years survived through study completion.

Production and survival rates for lambs born on the study area were high for both bands, with the exception of the Squaw transplants in 1988. Blood pregnancy tests indicated that at least 7 ewes were pregnant (4 were not tested) when transplanted to Squaw Creek in 1988 (Appendix, Table 13). Neonatal (<1 month age) mortality was extreme for Squaw transplants in 1988, with only 3 lambs (23 lambs: 100 ewes) surviving when all ewes had returned from lambing areas in late June (Table 4). Ten lambs were produced at Squaw Creek in 1989 (67 lambs:100 ewes), and 7 lambs were counted in July 1990 (39 lambs:100 ewes). Survival of lambs greater than one month of age through their first year to yearling age averaged 86.7% for the Squaw band in 1988 and 1989.

Nine ewes that tested pregnant in February 1989 survived to lamb at the Quake winter range in June 1989. Eight lambs (61 lambs:100 ewes) were counted when all ewes returned from lambing areas. Seven lambs (87.5%) survived to yearling age. Seven lambs (born in June) were counted in July 1990.

The Squaw transplant band totaled 36 sheep in July 1990. This represents a 74% increase from the 19 released in January 1988 or a 25% increase per year. The final classification included 11 rams (31%), 18 ewes (50%), and

Table 4. Classification counts of transplanted sheep conducted at Squaw Creek and Quake Lake winter ranges during summer and winter, 1988-1990.

Transplant Band and Date	Total Sheep	Rams - by Horn Curl <1/4	1/4	1/2	3/4	Tot. Rams	Ewes Adult No.	Adult $\bar{x}$ Age	Yrlg.	Lambs M	F	UN[a]	Number: 100 Ewes Lambs	Rams
Squaw Creek														
Winter 88[b]	19		1	1		2	9	5.0	2	4	2		54	18
Summer 88	22		5	5		6	11	4.6	2	2	1		23	46
Winter 89	22		4	2		6	11	5.1	2	2	1		23	46
Summer 89	33		6	1	1	8	14	4.6	1	3	3	4	67	53
Winter 90	29		2	5	1	8	14	5.1	1	3	3		40	53
Summer 90	36		3	6	2	11	15	5.3	3			7	39	61
Quake Lake														
Winter 89	23		1	1		2	12	3.9	4	2	3		31	12
Summer 89	24		2	1		3	10	3.6	3	4	4		61	23
Winter 90	22		2	1		3	10	4.1	2	4	3		58	25
Summer 90	29		4	2	1	7	12	4.2	3			7	47	47

[a] UN = unclassified.

[b] Winter classification counts (January-March), summer classification counts (June-August).

7 unclassified lambs (19%). The Quake transplant had increased from 23 to 29 sheep at completion of the study. This represents a 26% overall or 13% per year increase. If the 6 sheep that died shortly after release are not included, the overall increase is 71%, which is 35% per year. This total included 7 rams (24%), 15 ewes (52%), and 7 unclassified lambs (24%). The age class structure of the 2 groups differed (Table 5). The Quake band was younger, with yearlings representing the largest age class (24%). The Squaw band had yearlings and 3-year-olds both representing 18% of the total.

Native Sheep Bands

Population data for remnant native Hilgard sheep bands were summarized by the two main winter ranges (Squaw Creek and Quake Lake), as winter classification counts were the most consistent data source (Table 6). Seven native sheep were counted during winter-spring 1988 at Squaw Creek. Two ewes, two lambs, and a yearling ram wintered at the traditional winter range (with the transplanted sheep). Two older rams (1/2 curls) that wintered on ram winter range 2 km to the south appeared at Squaw Creek in mid-May while migrating to summer range. Sixteen natives were classified at the SC winter range in 1989, and 12 natives were counted in 1990. An average ratio of 72 lambs:100 ewes was obtained for winter counts 1988-1990.

Table 5. Numbers and percentages of sex and age classes for transplanted sheep on Squaw Creek and Quake Lake ranges at completion of study in July 1990.

Transplant Band	Age Class										
Sex	Lamb	1	2	3	4	5	6	7	8	9	Total
Squaw Creek											
Male		3	2	4	1	1					11
(%) SC[a]		(9)	(6)	(12)	(3)	(3)					(33)
Female		3	2	2	2		1	3		2	15[b]
(%) SC		(9)	(6)	(6)	(6)		(3)	(9)		(6)	(45)
Total	7[c]	6	4	6	3	1	1	3		2	33[b]
(%) SC	(21)	(18)	(12)	(18)	(9)	(3)	(3)	(9)		(6)	
Quake Lake											
Male		4	2	1							7
(%) QL[a]		(13)	(6)	(3)							(24)
Female		3	3	1	1	5	1	1			15
(%) QL		(10)	(10)	(3)	(3)	(17)	(3)	(3)			(51)
Total	7[c]	7	5	2	1	5	1	1			29
(%) QL	(24)	(24)	(17)	(6)	(3)	(17)	(3)	(3)			
Total Sheep	14	13	9	8	4	6	2	4		2	62[b]
(%) of Total	(22)	(21)	(14)	(12)	(6)	(9)	(3)	(6)		(3)	

[a] SC = Squaw Creek, QL = Quake Lake.

[b] Data excludes 3 adult ewes that were not aged during 1988 transplant.

[c] Unclassified lambs.

Table 6. Winter classification counts of native Hilgard sheep conducted at Squaw Creek and Quake Lake winter ranges, 1988-1990.

Native Band and Date	Total Sheep	Rams - by Horn Curl						Ewes		Lambs	Number:100 Ewes	
		<1/4	1/4	1/2	3/4	3/4+	Tot. Rams	Adult	Yrlg.	No.	Lambs	Rams
Squaw Creek												
Winter 88[a]	7		1	2			3	2	[b]	2	100	150
Winter 89	16	2		1	1		4	8		4	50	50
Winter 90	12			1	1		2	6		4	67	33
Quake Lake												
Winter 88	8[c]											
Winter 89	13			2	1	1	4	6	1	2	29	67
Winter 90	20		1	2	1	3	7	6	2	5	62	87

[a] Winter classification counts conducted January-March.

[b] All ewes classified as Adult; distance too great to determine yearlings.

[c] Sheep not classified.

Winter classification counts at the QL winter range produced 8, 13, and 20 native sheep in 1988, 1989 and 1990, respectively. The average lamb:ewe ratio was 46:100 for winters 1989-1990.

Seasonal Distribution and Movements

Aerial and ground relocations were used to determine seasonal distribution and movements of sheep bands. Twenty-seven flights were made from May 1988 through June 1990 (1988 = 9, 1989 = 13, 1990 = 5). Seven distinct bands (native and transplanted) were identified in the study area based on movements and winter/summer range selection and use. Presence of collars, group size, composition, and unique characteristics of unmarked native sheep (horn size, scars, etc.) were used to identify and track bands.

The bands were identified by winter range affiliation and include 3 bands that winter on or near the Squaw Creek winter range (Transplants, Native Ram, Native Ewe) and 4 bands that winter at the Quake Lake winter range (Transplants, Native Ram, 2 Native Ewe bands). Although these bands utilized common winter ranges, their selection of and movements on other seasonal ranges were independent (Figure 3).

Native Sheep Bands

The Squaw native ewe band began migration to lambing and summer ranges in early to mid-May. Lambing occurred in the Papoose Creek drainage, 6.4 km (straight-line distance) south of the winter range (Figure 3). Although ewes with newborn lambs were never observed, lambing areas were probably in the cliffs on the north side of Papoose Creek near the mouth. This ewe/lamb band utilized high elevation summer and fall ranges on the east side of the range at the head of Papoose Creek and along the divide between Hilgard Creek and the West Fork of Beaver Creek. Maximum distance between winter and summer ranges was 13 km.

Fewer relocations of the Squaw native ram band were made. The band size varied from 2-4 rams, dependent upon season. Yearling rams generally wintered at Squaw Creek with the native ewe band. Older rams wintered on southwest aspects between the Middle and South Forks of Squaw Creek and on the north side of the mouth of Papoose Creek (2.4 km and 5.6 km south of Squaw winter range) depending upon weather conditions (Figure 3).

In mid-May, 2 native rams (1/2 curl, 5/8 curl) moved from the Middle Fork of Squaw Creek onto the main winter range and joined with a native yearling ram and 2 transplant rams. This group moved together for 7 days on the winter range and 1.5 km up the North Fork of Squaw Creek. The

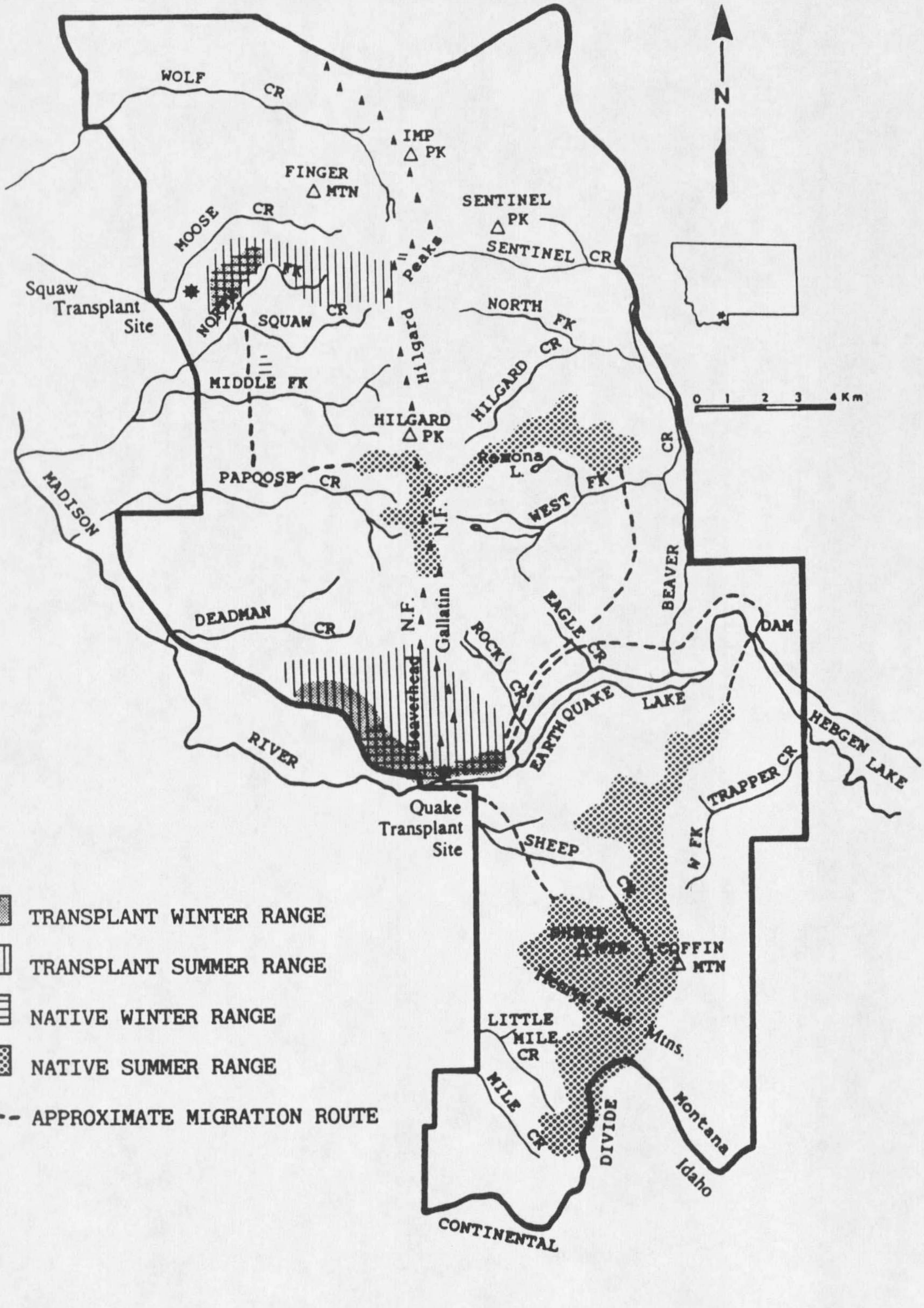


Figure 3. Minimum seasonal ranges and approximate migration routes of seven distinct sheep bands inhabiting the study area.

natives then migrated to summer range, and the transplant rams remained with the Thompson Falls ewes on winter range.

Four native rams were observed migrating with 12 native ewes in late May 1989 near the mouth of Papoose Creek. Summer relocations were made on the divide between Hilgard Creek and West Fork Beaver Creek. Other historic summer/fall ram ranges (Merritt Pride, pers. comm., July 1988) were frequently searched with a spotting scope or during flights, but no observations were made. A 3/4-curl native ram was observed on the Squaw Creek winter range with the transplant band during a December 1989 flight.

Delineation of seasonal ranges and movements of native bands that wintered at Quake Lake was aided by two radio-collared native ewes. The ewes were members of 2 distinct ewe/lamb bands. Dispersal of natives from the winter range began in mid-May. The ewe bands migrated along different routes to summer ranges south of Quake Lake in the northern Henrys Lake Mountains.

One band (with collared ewe 153.209) moved east along the timbered face north of Quake Lake, across Beaver Creek and Cabin Creek to Hebgen Dam (Figure 3). Lambing areas were assumed to be in cliff outcrops along the face between Rock Creek and Beaver Creek (approximately 6 km from winter ranges). The first native lamb was observed June 17 just east of Eagle Creek (2560 m elevation). This ewe/lamb band was observed as late as July 1 on a cliff ridge (Hebgen

Ridge) to the northeast of Hebgen Dam. Frequent movements were made in June across Highway 287 and Hebgen Dam to a salt block that had historically been placed on the southwest side of the dam. Rock outcrops above the dam were also used. The band moved across the dam in early July to higher elevation summer range in the Henrys Lake Mountains. Core summer range areas for this band were on the east side of the range, although they were located near Sheep Mountain and in Mile Creek on the west side (Figure 3) in late August and September.

The second Quake native ewe band (with collared ewe 153.401) crossed the Madison River and migrated south along the west front of the Henrys Lake Mountains to lambing areas in rugged cliff terrain on the south side of Sheep Creek drainage. This band summered mainly on the west side of the range in the Sheep, Mile, and Little Mile drainages, but were observed on east side locations used by the 153.209 band in early September.

Native ewe band summer ranges overlapped spatially but not temporally. Band movements were independent. Both groups moved frequently between isolated patches of summer range. The maximum distance between winter range and summer range relocations was 13 km. The two bands were observed together during the breeding season on the Continental Divide (3050 m) at the head of Sheep and Little

Mile Creeks in early December. Migration to the Quake winter range (10 km) occurred in late December.

The Quake native ram band moved off the winter range in early June. They migrated along the timbered face on the north side of Quake Lake to Beaver Creek; and then along the rugged west face of Beaver Creek to summer range on the divide between Hilgard Creek and the West Fork Beaver Creek (12 km) (Figure 3). Arrival on summer range was in early July. Six rams (3/4+, 3/4, 5/8, 1/2, 1/2, 1/2 curl) were observed on this summer range in 1989, and 5 were located in 1990. Three rams (3/4+, 3/4, 1/2 curl) from this band were located on the Quake winter range at a mineral lick in late August. Three rams were also seen with 22 transplanted sheep on the Quake winter range in late October 1989.

Transplanted Sheep Bands

Following the release of 19 sheep at the base of Squaw Creek winter range in January 1988, 11 sheep established themselves on the historic winter range. Eight sheep moved 2.5 km north to slopes above Moose Creek. Within 10 days, all 19 were relocated on the Squaw winter range. The transplant sheep concentrated their activities in a 18 ha core area (10% of the total available winter range) of open grass slope adjacent to cliffs that served as escape terrain through winter and spring (Figure 4). Native sheep frequently used the same area and were observed foraging with transplanted sheep, but movements of the two bands were independent. Transplant sheep utilized a larger percentage (40%) of the winter range during spring green-up of vegetation.

Ewes dispersed to lambing areas in early May. The first lamb was observed with a transplant ewe on May 14, 1988 in the cliffs adjacent to the core wintering area (0.5 km) on the Squaw range. Three ewes moved 2 km to cliffs at the mouth of Moose Creek to lamb, and 1 ewe lambed on cliffs above the mouth of Wolf Creek, 6.5 km from the winter range. Following lambing, ewes returned to the winter range and remained within 1-2 km of it through mid-June.

In late June transplant ewes and rams moved 3-4 km up the North Fork of Squaw Creek (Figure 4). The divide between Moose Creek and the North Fork of Squaw Creek, with elevations to 3330 m, was utilized as the core summer range through mid-August. Exploratory movements by rams up to 7 km occurred, but they rejoined the ewe band within a few days. Movements between summer and winter ranges were frequent during August, with more activity concentrated on the winter range into the fall. The rut occurred on the Squaw winter range.

The Squaw transplant band exhibited similar movements and seasonal range use patterns through June 1990.

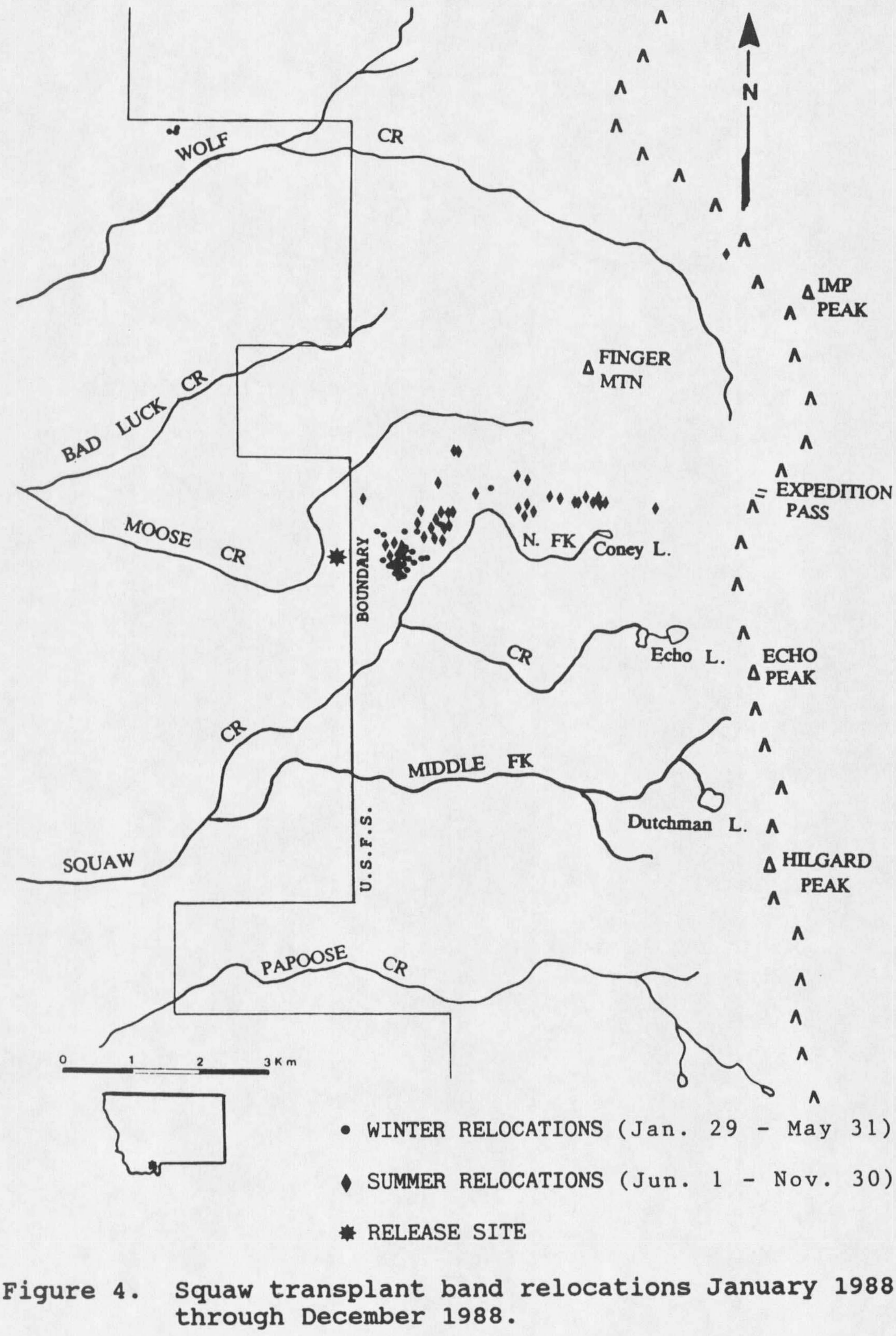


Figure 4. Squaw transplant band relocations January 1988 through December 1988.

However, the band did expand their summer and winter ranges, and exploratory movements became more frequent and lengthy (Figures 5, 6). During the winters of 1989 and 1990, the transplants utilized the entire winter range, a pattern of use similar to that of native sheep. Summer range was expanded in 1989 to include the alpine meadows at the head of the North Fork Squaw drainage and the adjacent ridges and peaks. Ram exploratory movements continued, with a 3-year-old collared ram moving 6.5 km south of the winter range with 2 other rams (ear tagged 2-year-old and yearling) during October-November 1989. The rams returned to winter at Squaw Creek. A native 3/4+ curl ram was observed with the transplant band during the 1989 rut at Squaw winter range.

By contrast, the Quake Lake transplant sheep made numerous exploratory movements during their first winter (1989) and utilized winter range areas outside of the historic native winter range. Two Thompson Falls lambs survived the initial transplant. The female lamb joined the native sheep, and the male joined the Lost Creek transplant band. The transplants used the timbered Quake winter range with the natives, but they also used open grassland-sagebrush slopes up to 2.5 km northwest of areas used by native sheep. A transplanted yearling ewe moved 4 km north of the winter range in late February. She was relocated during a flight in early April, 2 km further

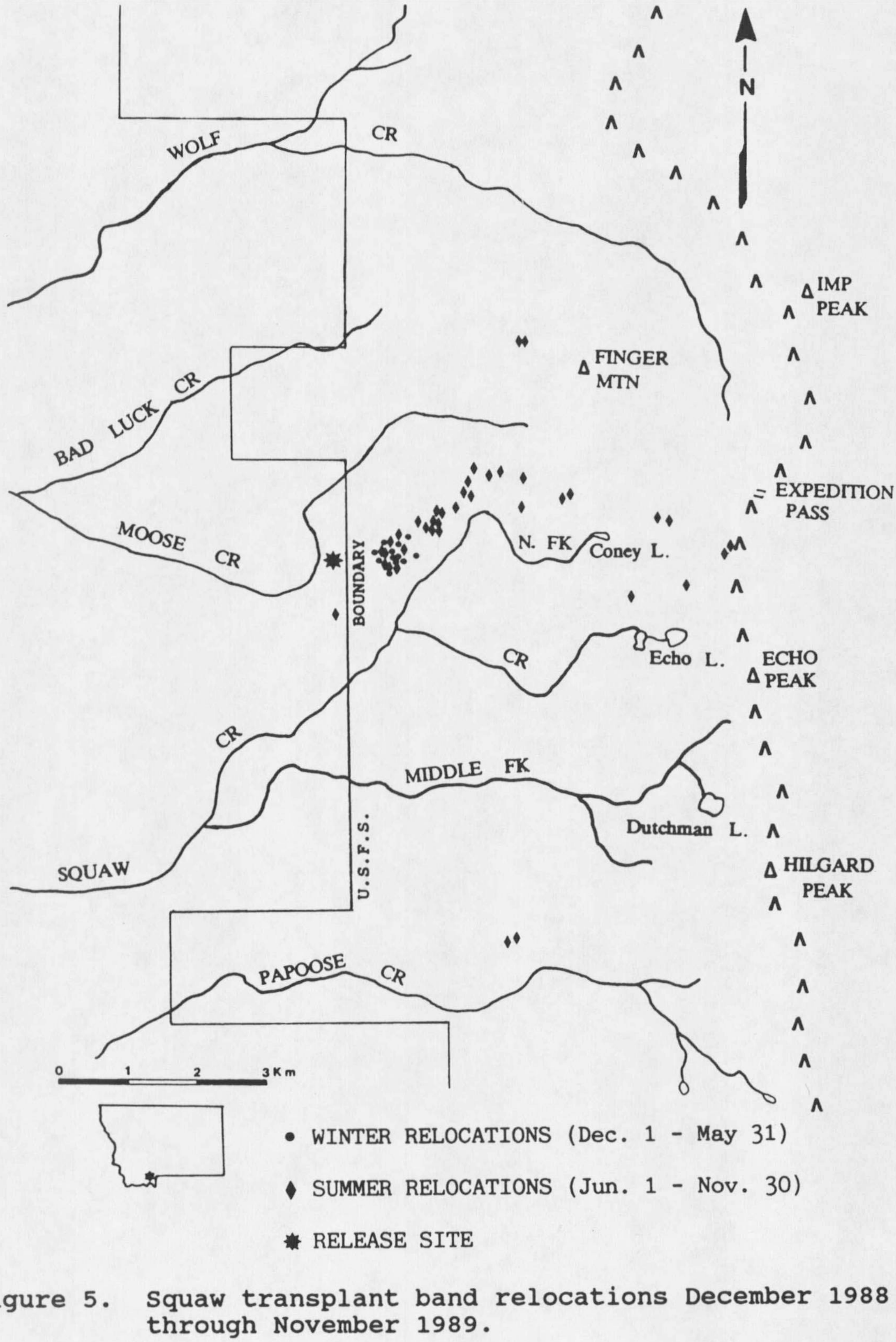


Figure 5. Squaw transplant band relocations December 1988 through November 1989.

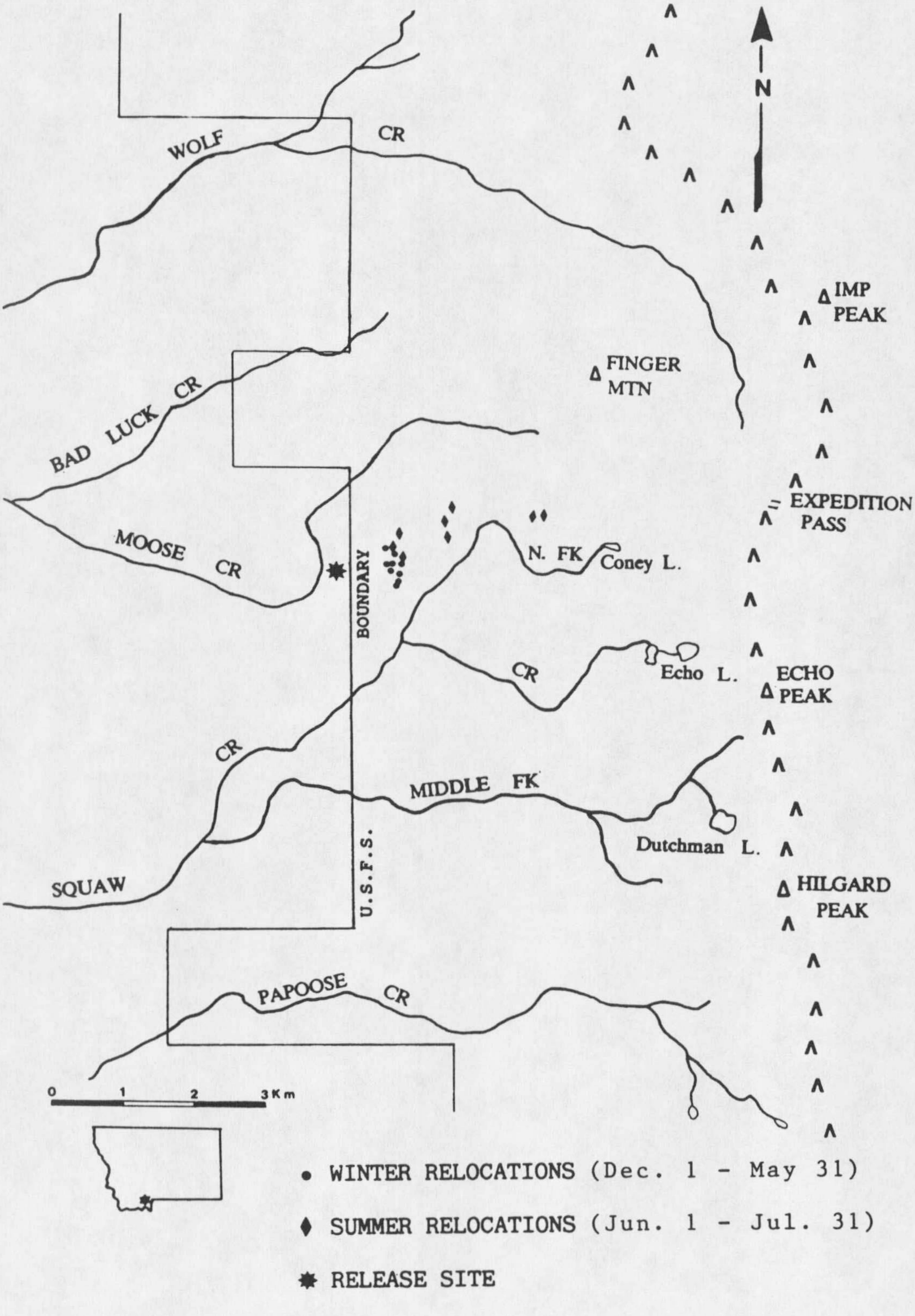
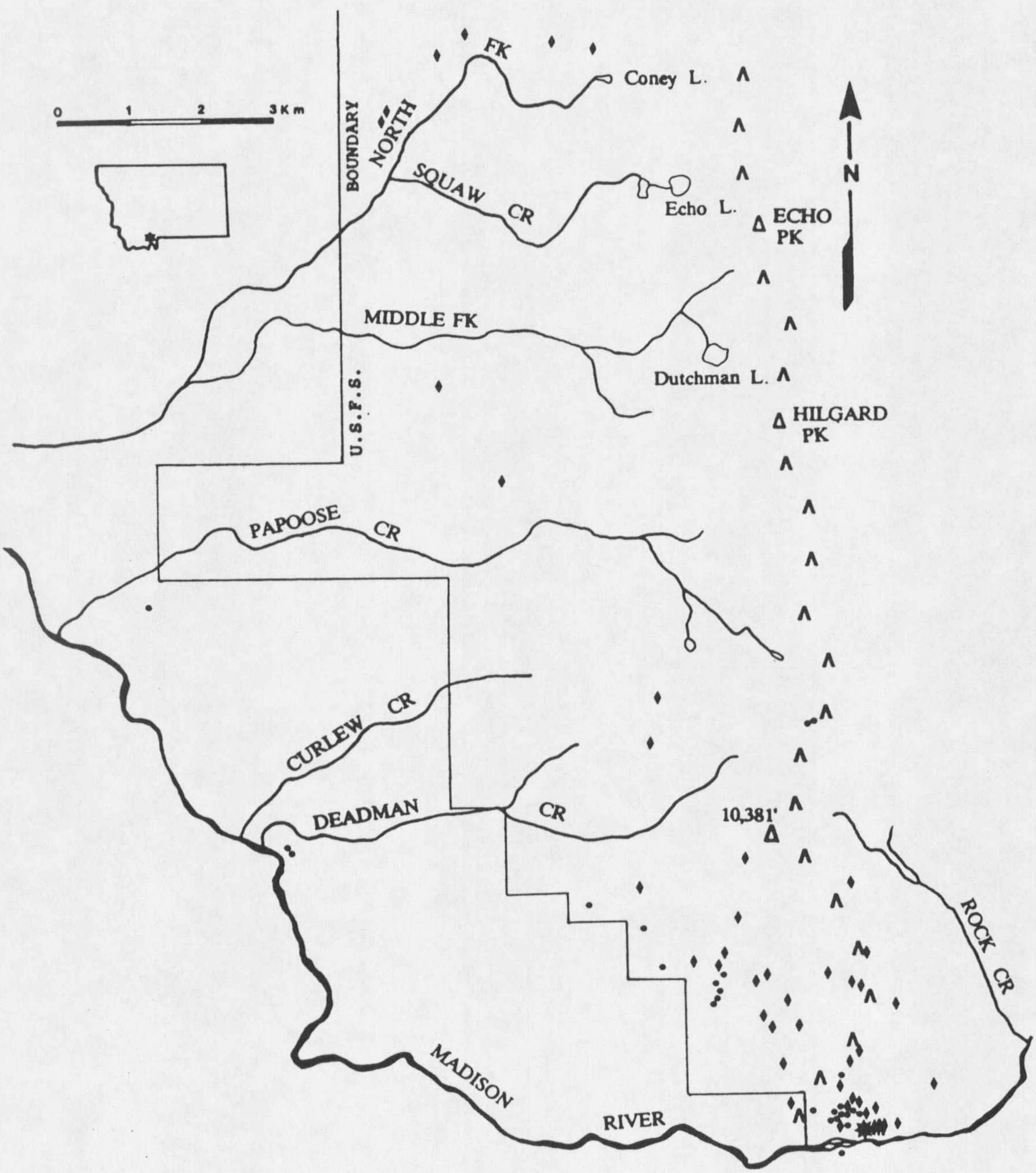


Figure 6. Squaw transplant band relocations December 1989 through July 1990.

north on a windswept 3195 m peak. She remained there until late May when she moved to the Squaw Creek winter range to join the transplant band in mid-June. Another ewe moved 8.5 km northwest with a native 3/4+ curl ram in March. They remained for approximately 2 weeks on a hillside above Highway 287 before returning to the Quake winter range (Figure 7).

The transplant sheep lambed in cliff outcrops on the winter range. The first lambs were seen on 1 June. Ewe/lamb groups remained on the winter range until late June, where they made heavy use of a mineral lick. Summer range establishment consisted of a gradual elevational movement to a ridge above the winter range that divided the Madison Valley from Rock Creek. The greatest elevation was 3080 m. Maximum distance traveled to summer range was 4 km.

Summer range use expanded through the summer. Frequent movements from higher elevations to the winter range mineral lick were made throughout the summer (Figure 7). Ewes moved independently or in small groups of 2-4. The Lost Creek 2-year-old ram made numerous exploratory movements and moved independently of the ewe/lamb groups. The ram frequented a high elevation cirque 6.8 km north of the winter range. In mid-September, the transplant sheep moved to lower elevations and were



• WINTER RELOCATIONS (Jan. 13 - May 31)

♦ SUMMER RELOCATIONS (Jun. 1 - Nov. 30)

✸ RELEASE SITE

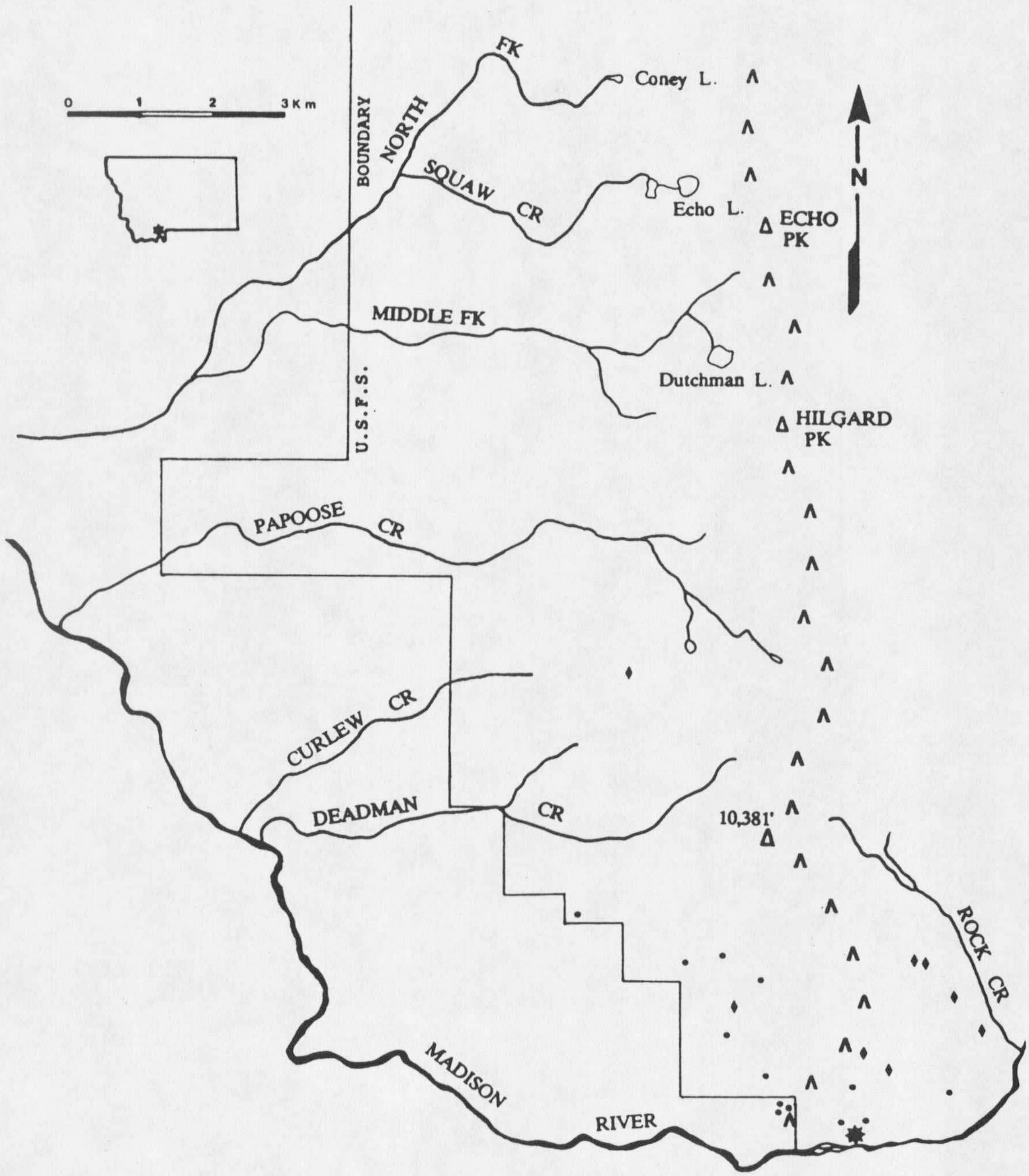
Figure 7. Quake transplant band relocations January 1989 through November 1989.

observed more frequently on the winter range. The rut occurred on the Quake winter range.

Similar movement and range use patterns were observed in 1990 (Figure 8). The transplant band continued to use the grassland-sagebrush communities on slopes north of the core winter range. Spring range use expanded to include Deadman Ridge, 4.5 km to the north. Lambing range expanded, with ewes lambing in cliffs above the core winter range and 2.8 km east in the cliffs on the west side of Rock Creek. The ewe/lamb band remained in Rock Creek through June, when they moved to higher elevation summer range.

Habitat Use

The Squaw Creek winter range encompassed approximately 180 ha of mountain grassland slopes, patchy timber, rock outcrops, and cliffs at elevations of 2440 m to 2840 m. Southwest to south aspects were dominant. Native rams also occasionally used a windblown ridge (approx. 30 ha, 2590 m elevation) 2 km south of the main winter range (Figure 3). Foraging areas, steep herbaceous slopes dominated by grass-forb communities with widely scattered timber patches, comprised about 70% of the winter range. Thirty percent was timbered escape terrain dissected by cliffs, rock outcrops, and avalanche chutes.



• WINTER RELOCATIONS (Dec. 1 - May 31)

♦ SUMMER RELOCATIONS (Jun. 1 - Jul. 31)

✸ RELEASE SITE

Figure 8. Quake transplant band relocations December 1989 through July 1990.

The Quake Lake core winter range included approximately 200 ha of south-oriented timbered slopes with numerous rock outcrops, cliffs, and avalanche chutes at elevations of 1925 m to 2320 m. Native sheep utilized only this steep timbered face. Transplanted sheep also used an additional 180 ha of southwest facing grassland-sagebrush slopes up to 2.5 km to the north (2075 m - 2320 m). The core winter range was 100% timbered with stands of varying canopy closures. The addition of 180 ha of grassland slopes to the core winter range resulted in an area utilized by transplanted sheep that was 47% open herbaceous and 53% timbered slopes.

Both transplanted sheep bands established summer ranges on higher elevation ridges and peaks adjacent to winter ranges. The Squaw band summered on a rugged ridge with peaks to 3335 m. Cliffs, talus, and avalanche chutes were present at all elevations. Alpine vegetation was dominant at elevations above 2682 m, and scattered timber patches and mountain grassland were dominant at lower elevations. They also used alpine meadows with grass/sedge/forb vegetation at the head of the North Fork of Squaw Creek (3170 m) (Figure 5).

The Quake band utilized a lower elevation (highest peak 3165 m) summer range. This area consisted of a long timbered ridge. Finger ridges separated by steep drainages characterized the west side of the main ridge. Cliffs, talus, and avalanche chutes were dominant landforms on the east side overlooking Rock Creek (Figure 7).

All native sheep bands migrated to high elevation (2850 m - 3350 m) summer ranges on broad ridges, peaks, and cirques. Areas used were characterized by alpine herbaceous vegetation in meadows and side slopes, scattered patches of stunted timber, and easy access to cliffs used as escape terrain (Figure 3).

Habitat use on winter and summer ranges differed among the 4 main sheep groups (Table 7). The Squaw transplants and natives used similar habitat components during winter with the majority of relocations occurring in the grass-forb cover type on southwest facing sidehills or ridges at elevations of 2439-2590 m. Chi-square analysis of use of cover type and terrain type habitat components on winter range showed no significant ($P>0.05$) differences between Squaw transplant and Squaw native sheep (Tables 8, 9).

The Quake transplant and native bands exhibited greater differences in their use of winter range habitat components than the Squaw bands, but differences were not significant. Quake transplants mainly used timber (closed) and grass-forb types on sidehills and ridges with southwest exposures at 1821-2133 m. The majority of native relocations occurred at the same elevations on south-facing sidehills with rock-bare ground, grass-forb, and timber cover types (35%, 29%, and 29%, respectively) (Table 7).

Table 7. Percent use of habitat components on winter and summer ranges by transplanted and native sheep bands in the Hilgard study area, January 1988-July, 1990.

	SCT[a]		SCN		QLT		QLN	
Habitat Component	Winter[b] (56)[c]	Summer (79)	Winter (40)	Summer (14)	Winter (33)	Summer (51)	Winter (17)	Summer (31)
Cover Type								
Timber-closed		5.1		7.1	39.5	33.3	29.4	16.1
Timber-open	16.1	25.3	17.5	14.3	5.3	9.8	5.9	6.5
Grass-forb	66.1	58.2	65.0	64.3	34.2	31.4	29.4	33.7
Shrub	8.9	1.3	5.0	7.1	5.3			
Rock-bare ground	8.9	10.1	12.5	7.1	15.8	25.5	35.3	38.7
Terrain Type								
Cliff	5.4	8.9	5.0		2.6	15.7	11.8	25.8
Sidehill	42.9	54.4	45.0	57.1	34.2	19.6	35.3	22.6
Ridge	33.9	19.0	25.0	21.4	31.6	23.5	5.9	19.4
Rock outcrop	5.4	2.5	10.0		10.5	9.8	11.8	12.9
Broken	12.5	11.4	15.0		15.8	13.7	17.6	6.5
Avalanche chute		3.8		21.4	5.3	17.6	17.6	12.9
Elevation (m)								
1821-1981					26.3	7.8	47.0	6.5
1982-2133					36.8	13.7	29.4	9.7
2134-2286			2.5		13.2	13.7	11.8	
2287-2438	7.1				15.8	21.6	5.9	16.1
2439-2590	75.0	13.9	57.5		2.6	9.8	5.9	9.7
2591-2743	16.1	32.9	35.0			5.9		6.5
2744-2895	1.8	24.0	5.0	14.3		15.7		12.9
2896-3047		8.9		64.3		11.8		29.0
3048-3200		12.7		21.4	5.3			9.7
3201-3353		7.6						

Table 7. Continued.

Habitat Component	SCT[a] Winter[b] (56)[c]	SCT Summer (79)	SCN Winter (40)	SCN Summer (14)	QLT Winter (33)	QLT Summer (51)	QLN Winter (17)	QLN Summer (31)
Aspect								
N		6.3		7.1		2.0		
NE		1.3		21.4		2.0	5.9	12.9
E				14.3		3.9	5.9	9.7
SE	1.8	25.3	5.0		15.8	21.6	17.6	41.9
S	30.3	13.9	20.0	28.6	26.3	17.6	58.8	9.7
SW	55.4	41.8	50.0	7.1	55.3	47.0	11.8	22.6
W	12.5	10.1	25.0	7.1	2.6	5.9		3.2
NW		1.3		14.3				

[a] SCT = Squaw Creek Transplant; SCN = Squaw Creek Native; QLT = Quake Lake Transplant; QLN = Quake Lake Native.

[b] Winter = December 1-May 31; Summer = June 1-November 30.

[c] Sample size = total number of observations. Observations are of groups of sheep.

Table 8. Results of Chi-square analysis (p-values) used to detect significant differences in cover type use by the 4 main sheep groups on the study area (on winter and summer ranges).

	STS[a]	STW	SNS	SNW	QTS	QTW	QNS	QNW
STS[a]	--	0.065	0.778	--	<.001	--	<.001	--
STW			--	0.846	--	<.001	--	<.001
SNS				0.932	0.013	--	<.001	--
SNW					--	<.001	--	<.001
QTS						0.107	0.117	--
QTW							--	0.126
QNS								0.743
QNW								

[a] STS = Squaw Creek Transplants Summer; STW = Squaw Creek Transplants Winter; SNS = Squaw Creek Natives Summer; SNW = Squaw Creek Natives Winter; QTS = Quake Lake Transplants Summer; QTW = Quake Lake Transplants Winter; QNS = Quake Lake Natives Summer; QNW = Quake Lake Natives Winter.

Table 9. Results of Chi-square analysis (p-values) used to detect significant differences in terrain type use by the 4 main sheep groups on the study area (on winter and summer ranges).

	STS[a]	STW	SNS	SNW	QTS	QTW	QNS	QNW
STS[a]	--	0.180	0.059	--	0.054	--	0.003	--
STW			--	0.836	--	0.441	--	0.204
SNS				0.011	0.077	--	0.048	--
SNW					--	0.658	--	0.063
QTS						0.227	0.798	--
QTW							--	0.194
QNS								0.472
QNW								

[a] STS = Squaw Creek Transplants Summer; STW = Squaw Creek Transplants Winter; SNS = Squaw Creek Natives Summer; SNW = Squaw Creek Natives Winter; QTS = Quake Lake Transplants Summer; QTW = Quake Lake Transplants Winter; QNS = Quake Lake Natives Summer; QNW = Quake Lake Natives Winter.

Observed differences in cover type use between the two winter ranges were significant (Table 8) and much greater than differences between transplant and native sheep on the same winter range. Squaw bands (native and transplant) made greater use of grass-forb types while Quake bands used predominantly timbered types.

Greater variability in habitat use by the 4 groups was evident on summer range. Squaw transplants selected grass-forb (58% of relocations) and open timber (25%) types on sidehills (54%) with southwest to southeast aspects at elevations 2591-2895 m (57%). Quake transplants used mostly closed timber, grass-forb, and rock-bareground (33%, 31%, 25%, respectively) cover types. There were significant differences between Quake and Squaw transplants on all terrain types. The sheep were located most often on southwest aspects at elevations ranging from 1821 m - 3047 m (Tables 7, 8).

Summer range habitat use by Squaw natives favored grass-forb (65%) sidehills with south and northeast aspects at 2896-3047 m. Quake natives summered in more rugged terrain with the majority of relocations made in rock-bare ground (39%) and grass-forb (34%) cover types. Most locations were in cliff (26%) and sidehill (23%) terrain on southeast aspects (42%) at elevations of 2896-3047 m (29%). Summer range cover and terrain type use was significantly different in comparisons of the Squaw transplant versus

Quake native and Squaw native versus Quake native (Tables 8, 9).

Factors Influencing Survival

Competition with Other Ungulates

Ungulate species observed on bighorn sheep winter and/or summer ranges during the study included elk, mountain goats, mule deer, and moose. A solitary cow moose was observed on only one occasion on the Squaw winter range (approx. 2440 m) in early June 1988.

A maximum of 25 mule deer were counted on the Squaw winter range in May 1988. Deer wintered at lower elevations than sheep (generally below 2380 m). Solitary or small groups of deer foraged at all elevations on the winter range during spring vegetation green-up and were occasionally seen on Squaw summer range.

Only 15 deer were counted on the Quake winter range. This is a minimum estimate since timber cover impaired observations. Deer used the same areas as sheep, but the two species were never observed together. Walking transects on the core winter range in May 1989 yielded a count of 34 deer carcasses. The area also served as a fawning/nursery range for mule deer in early summer.

MDFWP survey records indicated a dramatic increase in the number of elk wintering in Hunting District 362 from 1978 to 1990 (Table 10). Approximately 80%-85% (depending on winter severity) of elk counted during surveys winter in the Hilgard foothills and on the adjacent Madison River bench from Wolf Creek south to Papoose Creek (Figure 9). The wintering population was fairly low from 1965-1977 with a mean of 148 elk counted (range = 52-226). Elk numbers steadily increased after 1978, with 1,031 counted in 1982, the same year that the sheep decline began (Table 10). A regression analysis of sheep to elk numbers for 1978-1988

Table 10. Annual sheep and elk winter range census data (1977-1990) and mountain goat September census data (1985-1990) for the study area (MDFWP, unpublished data, 1990).

	Numbers		
Year	Sheep[a]	Elk[a]	Goats[b]
1990	83	2157	45[c]
1989	74	2356	182
1988	34	1723	ND[d]
1987	5	1157	226
1986	ND	1251	129
1985	ND	1330	17[c]
1984	9	1548	ND
1983	9	1481	ND
1982	23	1031	ND
1981	59	666	ND
1980	54	485	ND
1979	60	393	ND
1978	ND	420	ND
1977	46	216	ND

[a] Census conducted on winter range (Dec.-Mar.).

[b] Census conducted in September (Indian Creek south to Beaver Creek).

[c] Incomplete census data.

[d] No data - census not conducted in this year.

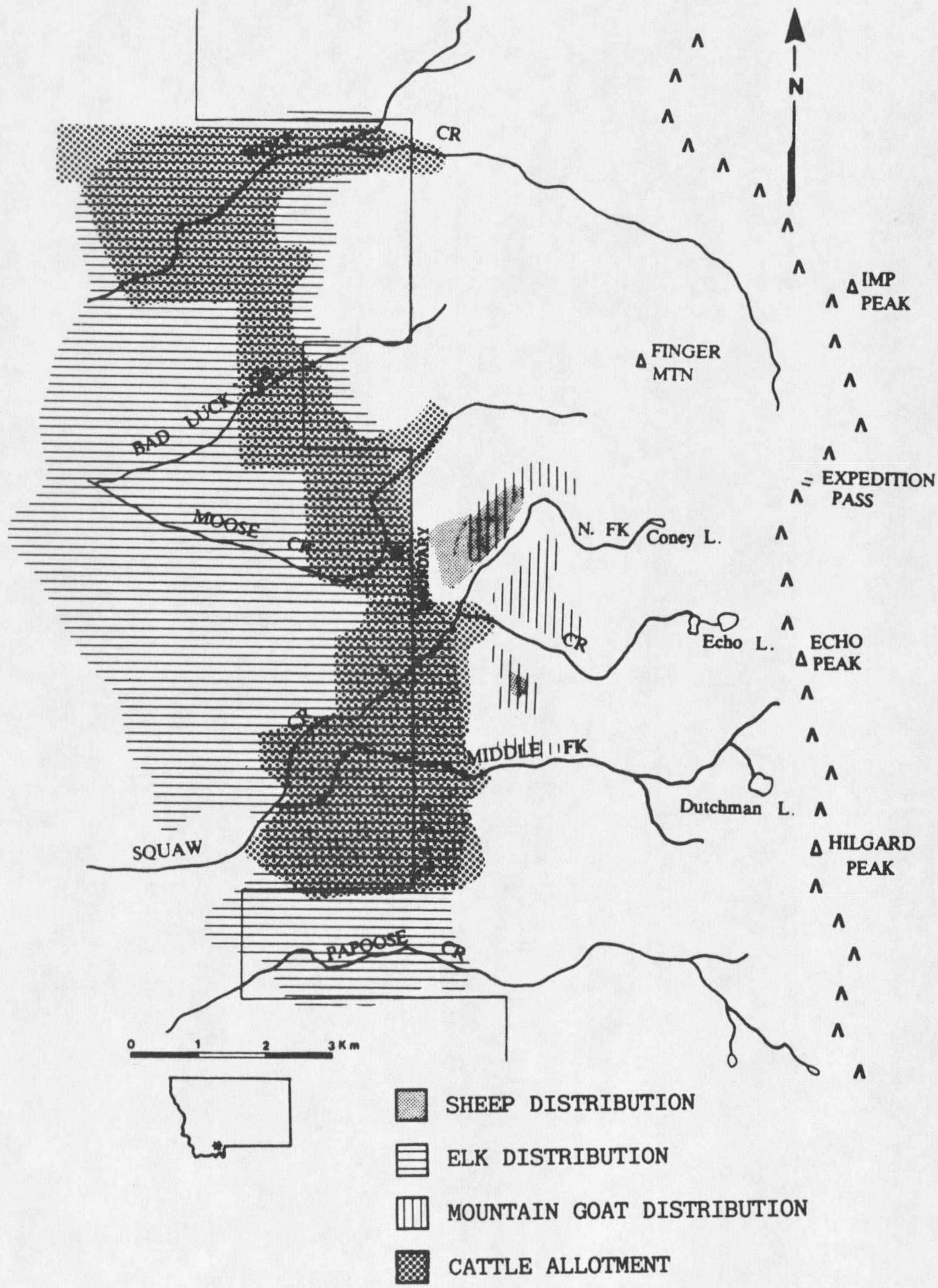


Figure 9. Winter (January through March) distribution of sheep, elk, and mountain goats between Wolf and Papoose Creeks (1988-1990).

demonstrated a significant negative correlation ($r=-0.90$, $P<0.001$). Sheep numbers decreased during the same period that elk numbers increased.

The distribution of wintering elk along the base of the Madison range depends mainly on aspect and wind-driven snow deposition patterns. MDFWP late season cow elk depredation hunts held in January and February also change distribution patterns. Based on 66 winter observation days, elk and sheep winter ranges (January through March) did not overlap during the study at Squaw Creek but did at Quake Lake (Figures 9, 10). Elk and elk tracks were observed at the base of the Squaw winter range and on an adjacent glacial moraine ridge but never above 2225 m. Approximately 15-20 elk wintered on the western end of the Quake core winter range in 1989 and 1990. Elk and sheep were never observed within 100 m of each other.

Spring and early summer elk use on the Squaw winter range was observed. Beginning in mid-April large groups (up to 200) of elk foraging on spring green-up of vegetation utilized elevations up to 2255 m. Groups of up to 80 were seen feeding at elevations of 2255 m - 2315 m, and small groups (<20) were observed at elevations up to 2560 m. The lowest elevation at which sheep were observed was 2380 m (Figure 11). The base of the winter range (2130 m - 2200 m) between Moose and Squaw creeks is an elk calving/nursery area and receives heavy spring-early summer

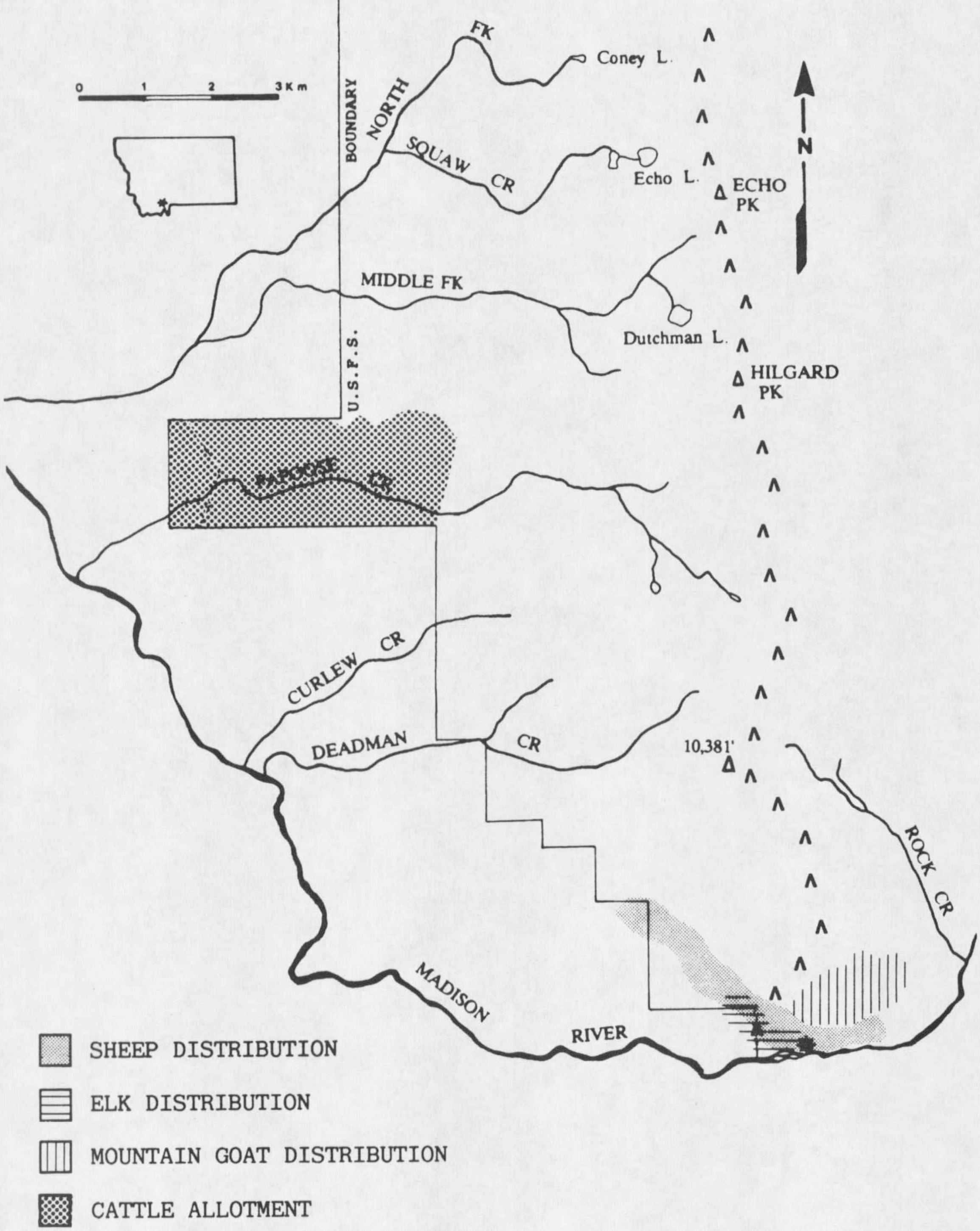


Figure 10. Winter (January through March) distribution of sheep, elk, and mountain goats on and adjacent to the Quake Lake winter range (1989-1990).

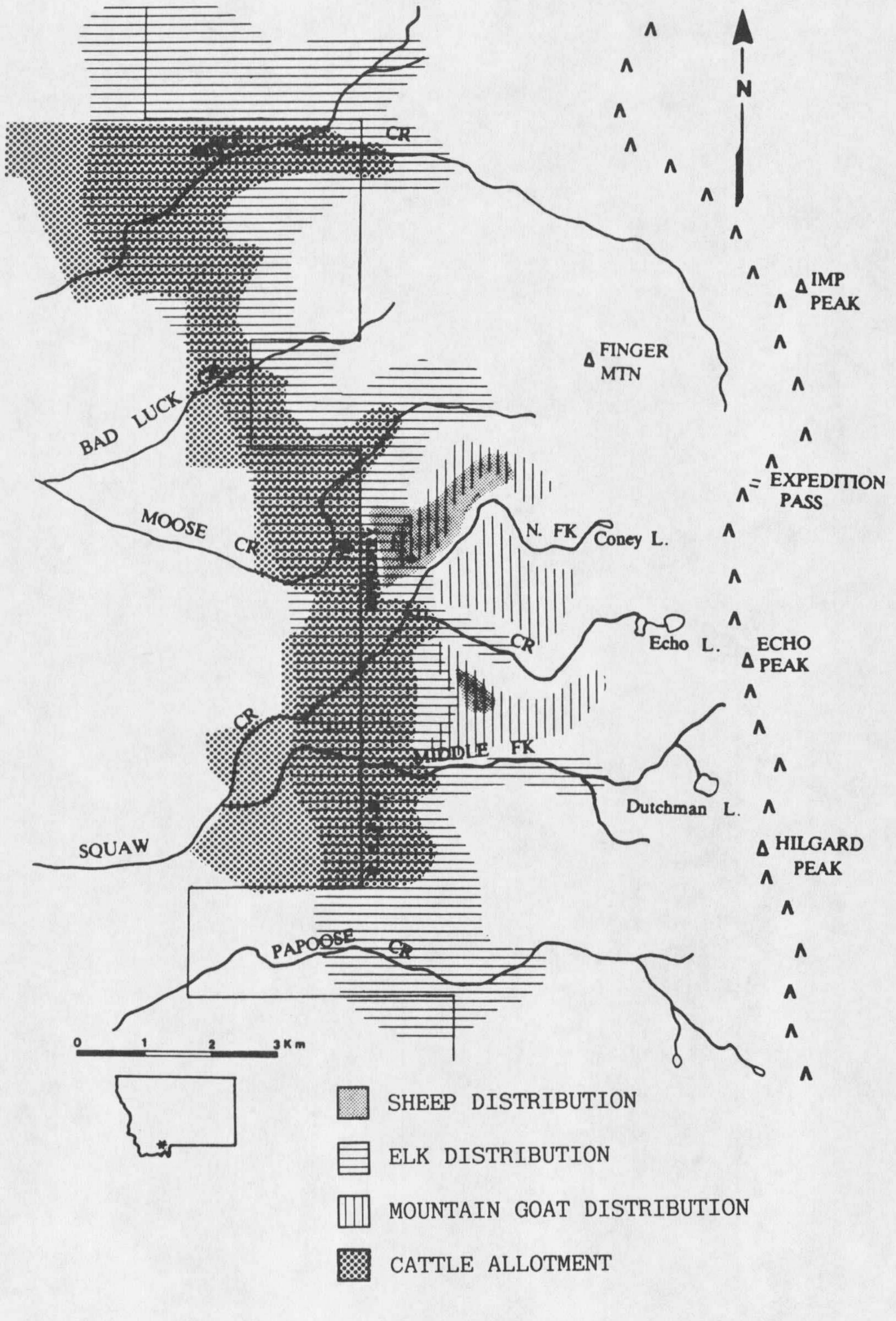


Figure 11. Spring (April through June) distribution of sheep, elk, and mountain goats on and adjacent to the Squaw winter range (1988-1990).

use. Late fall use of both winter ranges during elk migration was also suspected but not documented.

The mountain goat population in the Hilgard study area also increased during the 1980's (Table 10). Goats wintered on the Quake and Squaw winter ranges and were present on all sheep summer ranges in the Hilgards (Figures 9, 10, 11). Goats generally wintered 60 m - 120 m higher than sheep but were periodically observed foraging with sheep groups. During spring green-up, goats moved to lower elevations and foraged with sheep. Sixteen goats in 1988, 16 in 1989, and 18 in 1990 were observed foraging with sheep on the Squaw winter range (2460 m). No overt aggression was seen, but sheep avoided goats. Goats were observed displacing sheep from feeding sites and from beds on at least 4 occasions.

Domestic livestock including cattle, horses, and sheep were historically grazed in the southern Madison Range. Sheep were grazed on Forest Service allotments between Wolf and Squaw Creeks at the turn of the century (Tippets 1985, U.S. Dept. Agric. For. Serv. 1980). Since the 1940's cattle were grazed on 2 Forest Service allotments (Squaw-Moose and Papoose) and on private land along the western edge of the Hilgards (Figures 10, 11). Range management plans by the Soil Conservation Service and Forest Service set up a rest-rotation grazing system for the Squaw-Moose allotment in 1986 and directed that 60% of the total forage on the allotments be left for elk winter range.

The Squaw winter range is partially contained in the Squaw-Moose allotment. Cattle are grazed on the Moose pasture between July 1 and October 15 dependent upon the year. The pasture is rested every third year. No evidence was seen during summer observations and pellet transects that cattle have recently used elevations above 2377 m (Figure 11).

Habitat Adequacy

Plots clipped on Squaw winter range in 1988 were used to determine degree of winter forage utilization by sheep. Transplanted and native sheep (to a lesser extent) concentrated their winter activities on this area of the winter range because it was generally snow-free and was adjacent to cliffs used as escape terrain. More than 95% of observed ungulate use on the area was by sheep (approx. 5% mountain goat use).

Plots clipped in October 1987 indicated 63 g/m^2 of forbs were available for use by sheep during winter (Table 11). Clipping in April 1988, prior to the initiation of growth in grasses and forbs, indicated 9 g/m^2 of grass and 8 g/m^2 of forbs remained. Overwinter decreases were significant for both forbs and grass (t-tests, $P<0.05$).

Weathering loss over winter was assessed by comparing plots clipped outside forage cages in October with plots

Table 11. Results from 0.1 m^2 plots clipped on the Squaw Creek winter range in October 1987 and April 1988. Means are presented as g/m^2.

	Number of Plots	Mean weight (g/m^2)	
		Grass	Forbs
October - outside cages	15	63	35
April - outside cages	16	9	8
[% decrease (Oct. to Apr.)		86%	77%]
April - inside cages	12	38	28
April - outside cages	12	9	9
[% decrease (in vs. out)		76%	68%]

clipped inside cages in April (Table 11) using a Blocked Analysis of Variance (treatments = inside vs. outside; blocks = plots in and adjacent to individual cages). Mean values for grasses inside cages in April were significantly ($P<0.05$) lower than mean values for grasses outside cages in October indicating some overwinter loss due to weathering. There was no significant weathering loss in forb biomass between October and April.

Almost all grass plants were grazed by April, and the majority of the forb biomass remaining on this ridge was composed of nonpalatable species. Clipping indicated that 24 wintering sheep utilized most of the available forage on this ridge.

Disease, Accident and Weather

Thompson Falls sheep transplanted to Squaw and Quake ranges were infected with lungworm (Table 2). Native Hilgard sheep were found to be infected with lungworm in 1989 (Appendix, Table 19). There is a strong possibility that native sheep were infected in the early 1980's. I found no physical evidence to support or disprove the hypothesis that the decline in 1982-83 was due to lungworm-related pneumonia.

Weather during the study was generally warmer and drier than normal (Table 3). Weather data for the years preceding and during the Hilgard native decline (1979-1984) are shown in Table 12. Precipitation for 1982 was 11.78 cm above normal. Spring storms during March and April (+4.45 cm and +2.90 cm, respectively) and a mean April temperature -4.8°C below normal created harsh spring weather conditions. Annual precipitation for 1983 was 8.36 cm above normal.

Transects were walked on winter range and at the base of avalanche chutes to attempt to locate evidence of a catastrophic accident (such as sheep dying in an avalanche). Six sheep skulls were found (5 ewes on Squaw winter range, 1 ram on summer range), but only 2 were found in the same location at the base of an avalanche chute. Three sheep (2 native rams and 1 transplant ewe) were

Table 12. Mean temperature (°C), mean precipitation (cm), and mean departures from normal for 2-month intervals from December 1978-November 1984 at Hebgen Dam weather station (NOAA).

	December[a]-January				February-March				April-May			
	Temp. (°C)		Prec. (cm)		Temp. (°C)		Prec. (cm)		Temp. (°C)		Prec. (cm)	
Year	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$
1979	-16.2	-5.6	6.2	-1.5	-6.2	+1.1	8.2	+2.2	4.5	+0.4	2.5	-3.4
1980	-9.3	+1.2	5.3	-2.3	-4.7	+2.5	4.5	-1.4	5.7	+1.6	8.5	+2.6
1981	-7.2	+3.3	5.4	-4.5	5.0	+2.2	4.6	-1.3	5.3	+1.1	7.3	+1.4
1982	-9.7	+0.7	10.8	+3.1	-6.4	+0.8	10.9	+4.9	2.3	-1.8	8.2	+2.4
1983	-9.1	+1.3	8.8	+0.6	-4.4	+2.7	10.3	-3.9	3.3	-0.6	2.7	-3.3
1984	-12.5	-1.9	7.7	-0.9	-6.9	+0.1	6.4	+.02	2.9	-0.9	8.3	+2.3

	June-July				August-September				October-November			
	Temp. (°C)		Prec. (cm)		Temp. (°C)		Prec. (cm)		Temp. (°C)		Prec. (cm)	
Year	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$	$\bar{x}$	Dep. $\bar{x}$
1979	14.2	+0.6	3.2	-2.8	14.1	+1.4	5.8	+1.7	0.0	-0.5	4.9	-0.7
1980	14.3	+0.1	7.2	+1.1	12.4	-0.3	7.0	+2.9	1.0	+0.5	2.9	-2.7
1981	13.9	+0.3	6.0	-.05	14.8	+2.0	2.1	-2.0	1.4	+0.9	7.5	+1.9
1982	13.3	-0.3	6.1	+.05	13.6	+0.8	6.27	+2.1	-1.0	-1.5	6.5	+0.9
1983	13.2	-0.6	10.3	+4.0	13.6	+0.8	6.7	+1.9	1.7	+1.3	10.1	+5.0
1984	13.3	-0.5	11.9	+5.7	12.9	-0.3	6.3	+1.4	-0.8	-1.2	5.3	+0.3

[a] December data is from previous year.

killed on Highway 287 adjacent to the Quake winter range during 1989-90.

Predator and Hunter Mortality

Three predators known to kill sheep were present on the study area: coyote, mountain lion, and golden eagle. Coyotes were the most commonly observed predator on winter and summer ranges. Three observations of coyotes chasing and harassing sheep (2 ewe bands, 1 ram band) were made. No observations of coyotes actually preying on sheep were made. Hass (1980) reported nearly identical observations.

Mountain lion tracks in snow on the Quake winter range were seen on 2 occasions in 1989. A MDFWP biologist witnessed a mountain lion killing a ewe on the Squaw winter range in the early 1980's (Graham Taylor, pers. comm., 1988).

Two golden eagles perched within 10 m of sheep and hunted the Squaw winter range during winter-spring 1989-1990. Eagles were observed diving at transplant ewe-lamb groups on 4 occasions causing the sheep to run. Eagle pellets were collected and analyzed for sheep hair; results were inconclusive.

Mortality due to legal hunting was unlikely to have precipitated the decline in resident sheep during the early 1980's. Legal hunting was carefully monitored and limited to harvest of mature males (minimum 3/4 curl) for

2 decades. During the period 1974-1986, 16 rams were harvested from the Hilgards, and 5 rams were harvested from the Henrys Lake Mountains. No records of illegal harvest were found.

DISCUSSION

Population Dynamics

The Hilgard transplant was moderately successful in comparison with other bighorn sheep transplants in Montana's history (Rognrud 1983, Kopec 1982, Butts 1980, Janson 1974). A total of 42 sheep were transplanted into the Hilgards in 1988 and 1989, and by July 1990 their numbers had increased to 65 (Table 4). This represents a total increase of 55%, with a 74% increase over 2½ years (average increase 25% per year) in the Squaw Creek band, and a 26% increase over 1½ years (average 13% per year) for the Quake band.

Production was consistently higher in the Quake band with lamb:ewe ratios of 61:100 (1989) and 47:100 (1990). The Squaw band produced ratios of 23:100 (1988), 67:100 (1989), and 39:100 (1990). The lower average yearly increase (13%) for the Quake band was due to high adult mortality (6) during 1989, the winter following transplant (Appendix, Table 14). From all indications, the Hilgard sheep population is a rapidly increasing, high quality population (Geist 1983, Johnson 1980, Cook, 1990).

Transplanted sheep were in relatively good health when released in the Hilgards. Blood chemistry values were within normal ranges for Montana bighorns (Appendix, Table 16) and within ranges reported for other studies (Bottrell et al. 1978, Davies 1976). The Blood Urea Nitrogen (BUN) value for the Thompson Falls (TF) transplant sheep indicated they had high quality forage on the TF winter range, and were in superior nutritional health compared to the Lost Creek or Hilgard Native Sheep (Hebert 1978, Franzmann 1971). Six sheep tested positive for anaplasmosis (all Thompson Falls sheep) and 12 tested positive for leptospirosis (4 Thompson Falls, 8 Lost Creek). These positive tests cannot be considered conclusive evidence of past infections because conclusive results from a single blood test are not possible (MSU Marsh Vet. Lab, pers. comm., March 1991).

Fecal lungworm larvae counts for transplanted Thompson Falls sheep were well above historical levels for that herd (Table 2 and Appendix, Table 19). The inflated TF larvae per gram of feces (LPG) values for 1988 and 1989 may have resulted from fecal pellets being crushed prior to Baermann analysis rather than an actual increase in shedding. Crushing tends to increase larvae release from pellets (Beane and Hobbs 1983, Samuel and Gray 1982). Further, significant monthly and yearly variation in larvae output has been demonstrated (Yde et al. 1988, Forrester and Senger 1964); therefore, these data primarily indicate presence or absence of lungworm infection at time of sampling.

Transplacental transmission of lungworm larvae has been demonstrated and linked to decreased lamb survival (Festa-Bianchet and Samson 1982, Spraker and Hibler 1982, Hibler et al. 1974). This could be a concern for the transplant sheep. Of 11 Thompson Falls ewes transplanted to Squaw Creek in 1988, 100% of those tested (7) for pregnancy were positive. Although the Pregnancy Specific Protein B test used has been demonstrated accurate for mule deer, it has not been validated for bighorn sheep (R. Garth Sasser, pers. comm., 1991). Lungworm-related mortality is one possible explanation for the survival of only 3 lambs (observed in early July 1988) from a minimum of 7 pregnant ewes.

Counts of the remnant Hilgard native sheep population also increased during the study. Winter range counts in 1988-1990 showed a 71% increase for the 2-year period at Squaw Creek, and 150% at Quake Lake (Table 6). This increase could be totally or partially due to effects of weather on winter counts. The winter of 1988 was mild with above normal temperatures and below normal precipitation levels (Appendix, Table 20) and could have resulted in native sheep wintering on locations other than traditional winter ranges.

Movements and Habitat Use

The movements and gradual range expansion of the two transplant bands were characteristic of bighorn sheep transplanted into a new area (Stevens and Hanson 1986, Chow et al. 1988, Fairaizl 1980, Drewek 1970). Restricted habitat use by transplanted sheep during the first year and range expansion during the second year following release have been documented in other studies (Shaw 1986, Kopec 1982, Hass 1980, Bear 1979). Geist (1967, 1971), after reviewing information from bighorn reintroductions in the United States and Canada, concluded that transplanted sheep usually restrict habitat use to areas near the release site.

The Squaw transplant sheep wintered on a 18-ha core area (10% of the available winter range) within 800 m of the release site their first winter. The Quake transplants utilized areas within 1000 m of the release site for the majority of their first winter but did move up to 3.2 km away while foraging. Winter exploratory movements were more common with the Quake band. These sheep exhibited much lower group cohesion than the Squaw band. Quake sheep moved independently and in small groups, while Squaw sheep generally moved together as a band. This difference could be due to the trapping techniques used in the 2 transplants. The Squaw sheep were corral trapped, which tends to capture a group of sheep that are foraging together. The Quake sheep were captured by a helicopter drive-netting operation which randomly traps sheep from different bands utilizing the same winter range (Jessup et al. 1984).

Geist (1971) proposed that migration patterns and locations of seasonal ranges are learned by young natives and are thus passed through generations of bighorns. He also concluded that mountain sheep are gregarious and have open societies. These theories form the main premise behind transplanting sheep into historic range while a remnant population still exists. The transplants will, according to the hypothesis, remain in the area (and not disperse) because there are other sheep present. They will band together with the natives and learn traditional migration routes between prime seasonal ranges (Geist 1971), and there will be a mixing of gene pools to alleviate inbreeding depression (Ralls et al. 1986, Geist 1983, Skiba and Schmidt 1982).

The results of the first 2 years following transplant indicated problems with the concept of augmenting remnant native sheep populations. Transplanted sheep remained in the study area, but not because they joined native sheep bands. The transplant and native sheep in this study were frequently observed foraging in the same areas on winter range without any overt aggression. However, band movements were independent, and the transplants did not migrate to summer range with the natives (with the exception of one transplant lamb). Only 3 of the 42 Hilgard transplant sheep (all from the Quake band) joined with other sheep bands during the study. Similar observations were made by Stevens and Hanson (1986).

Summer range establishment was similar for both transplant bands. Movements to higher elevation ridges adjacent to winter ranges occurred in July. Winter ranges were used frequently throughout the summer. During the second summer at Squaw Creek, the transplants expanded their range and used the winter range less frequently.

Hilgard natives migrated long distances to reach specific isolated summer high elevation ranges. Johnson (1980) observed that sheep movements followed plant phenology through elevational migrations, which maximized protein, phosphorus and digestible energy intake during the summer. Hilgard ranges were mostly alpine meadows that offered minimal competition from elk or mountain goats. These ranges were all well removed from human recreation disturbance.

Yearlong use of winter ranges is a concern because it limits forage available during the critical winter months. Seasonal range choice is especially important to ewe groups (Festa-Bianchet 1986). Selection of marginal ranges in any season may have severe consequences for survival and reproductive success because it may result in poorer nutrition (Goodson et al. 1991) and/or increased exposure to parasites and disease (Stevens and Hanson 1986, Wishart et al. 1980, Spraker 1974). Transplant bands at Squaw Creek and Quake Lake would enhance the chances for long-term success if they expand their summer ranges and use winter ranges only during critical winter months. Observations from this study suggest that genetic interchange will occur; however, genetic benefits cannot be assessed for years and will be left to future studies.

Habitat use by transplanted sheep reflected habitat availability, as was concluded by Riggs (1977). Both transplant bands used a mix of forested and open cover types. The Squaw band utilized open-timber cover types on winter and summer ranges (Table 7). The Quake band used predominantly closed-timber cover types in winter and summer. The Squaw sheep utilized the grass-forb type throughout the year more than the Quake sheep did. The Squaw winter range was 70% herbaceous ground cover with scattered timber patches, and 30% escape terrain with open-timber and cliffs. The wintering area used by Quake transplants was 53% closed-timber and 47% herbaceous cover; and the adjacent summer range was also heavily timbered.

Traditional habitat use patterns in areas where transplanted sheep were captured evidently did not influence their habitat use at the release sites. The

Squaw transplants wintered on timbered, low-elevation slopes near Thompson Falls, yet did not select for similar habitat after release at Squaw Creek. The Quake transplants wintered on a higher elevation windswept herbaceous foothill area near Lost Creek, yet made heavy use of closed-timber cover types during winter and summer at Quake Lake (Table 7). This is contrary to Geist's (1971) theory that bighorn sheep avoid timber cover. This adaptability in habitat use was a significant factor in the success of the transplant.

Factors Influencing Survival

Several factors were identified as possible factors influencing the survival of Hilgard sheep. These included interspecific competition with elk, mountain goats and cattle, intraspecific competition by sheep for limited winter range, weather, predation, disease, catastrophic accident, and illegal harvest.

Interspecific competition for limited resources on Hilgard sheep winter ranges was not specifically tested, but the potential existed. Dietary overlap between sheep, elk, mountain goats, deer, and cattle has been demonstrated in various studies (Dailey et al. 1984, Stewart 1975, Constan 1972, Oldemeyer et al. 1971, Schallenberger 1966, Buechner 1960). Although cattle were grazed on private land and Forest Service allotments near the winter ranges, cattle summer utilization areas did not overlap sheep wintering areas. Deer use on the Squaw winter range was dispersed and minimal. Forage competition between deer and sheep could have occurred on the Quake winter range due to yearlong use by a larger number of deer.

Thorne et al. (1985) reported that elk numbers in south-central Montana were rapidly increasing on bighorn sheep winter ranges. Elk and mountain goat populations in the study area both increased in the 1980's (Table 10). Both species were observed on the Squaw and Quake winter ranges during the study. Mountain goats were observed on all sheep summer ranges in the Hilgards. Elk pellet groups were noted during pellet transects on sheep summer ranges, but elk were never observed there.

Competition between goats and sheep appeared to be minimal on summer ranges. Goats moved onto sheep winter ranges during spring and appeared to compete for vegetation green-up. Goats displaced sheep from foraging and bedding sites. Reed (1986) made similar observations.

Areas used by 15-20 elk that wintered on the Quake winter range overlapped those used by sheep, making competition a possibility. There was no observed overlap of elk and sheep winter ranges at Squaw Creek. Elk use of both winter ranges occurred in the spring and late fall, making indirect competition a possibility.

Intraspecific competition on winter ranges could likely be the major limiting factor to the Hilgard sheep population in the future. Numerous researchers have concluded that lack of suitable winter range is the limiting factor affecting sheep populations (Hoefs and Brink 1976, Constan 1975, Oldemeyer et al. 1971, Buechner 1960). Both winter ranges were marginal due to restricted size and large snow accumulations. The Squaw winter range was a high elevation (to 2840 m), windblown, steep foothill face with marginal forage productivity. Sheep utilized windblown snow-free areas on ridges near escape terrain. The Quake winter range was lower elevation (1925 m - 2195 m) but received greater snowfall without the benefit of wind scouring.

Three species of predators known to prey on sheep were observed on the study area: coyotes, golden eagles, and mountain lions (Harrison and Hebert 1988, Hebert and Harrison 1988, Hoefs 1979, Smith 1954). Encounters between sheep and coyotes were the most commonly observed, but no marked sheep were lost to predation. Predator numbers on the study area were assumed to be moderate to high in relation to recent historical levels. No predator control on private lands adjacent to the winter ranges was known to occur. The market for coyote pelts did not encourage trapping. Further, the MDFWP late cow elk hunt on adjacent private land most likely concentrated predators in the vicinity of winter range.

Other possible limiting factors to the Hilgard sheep population included disease, catastrophic accident, and illegal harvest. No marked sheep were known to have died of disease. Cause of death for the 6 Quake Lake transplant sheep (3 from Thompson Falls, 3 from Lost Creek) shortly after release is unknown but could have resulted from capture myopathy caused by stress from drive net trapping and handling (Lemos 1990, Spraker 1976). No catastrophic accidents occurred during the study, but 3 sheep (2 native rams, 1 transplant ewe) were killed on a highway adjacent to winter range. Illegal harvest during the study was evidently low. Sheep on the Quake winter range were highly visible from the highway and could have been illegally harvested with minimal risk to poachers. Two dead native rams without heads were found 60 m above the highway in April 1989.

The combined effects of these possible limiting factors were apparently low during the study, and both transplant and native sheep numbers increased. The influences of these factors in the Hilgard native sheep decline of 1982-83 was not determined. The sudden and catastrophic nature was characteristic of lungworm-pneumonia infection die-offs (Coggins 1988, Andryk and Irby 1986, Onderka and Wishart 1984, Wishart et al. 1980). Two fecal samples obtained from native Hilgard sheep in 1989 were positive for lungworm larvae. Although domestic sheep have not recently been grazed in the Hilgards, Forest Service sheep allotments are still active on the Targhee National Forest approximately 26 km southeast of Quake winter range. Transmission of highly virulent strains of Pasturella from domestic sheep to bighorns has been implicated in some other die-offs (Foreyt 1990, Coggins 1988, Goodson 1982). Whether this happened in the southern Madison Range in 1982-83 is unknown, but no other viable possibilities were discovered.

CONCLUSIONS

Transplanting bighorn sheep to augment remnant native populations on historic ranges could be beneficial in reversing the negative effects of inbreeding depression and in re-establishing huntable populations of sheep (if habitat is adequate). However, as evidenced by this study and others, sheep societies are not as open as originally thought and transplanted sheep do not necessarily join native bands. Transplant sheep tended to remain near the release site for 1-2 years and gradually expanded their ranges thereafter rather than follow movements of native sheep. There must be adequate resources (especially on winter ranges) to sustain heavy utilization during this period. The success of transplants can be jeopardized by marginal winter ranges and/or the presence of large populations of species that compete with sheep.

There should be a clearly defined objective for the desired optimal size of the sheep population at the transplant site. Managers should determine if this number is likely to be within the carrying capacity of the range considering use by sheep and other ungulates. Smith et al. (1990) developed a habitat evaluation procedure that aids in assessment of potential transplant sites as quality bighorn sheep habitat capable of producing minimum viable populations.

After sheep are transplanted, their survival and productivity should be monitored until numbers reach historic levels or transplant failure is indicated. Additional transplants should not be made if there is evidence that the current population is negatively impacting the most restricted part of their range (usually winter range).

Additional research is needed to determine how trapping methods influence the survival of transplanted sheep. Data from this study (N=2 transplants) suggests that corral trapping selects for social groups of sheep that tend to function as cohesive units after release into a new area. A possible negative impact of this technique could be the extirpation of an entire band of sheep from their original range. Helicopter drive-netting operations on large winter ranges randomly select for sheep from various bands. This study indicated that sheep trapped by this method had a greater tendency to disperse and pioneer new areas after the transplant. If this theory is proven through further research, managers could select trapping methods to meet transplant objectives.

Specific conclusions with regard to the Hilgard sheep transplants are:

1. Although intraspecific competition on winter ranges could likely be the major limiting factor to the Hilgard sheep population in the future, the strong negative associations between elk numbers and sheep numbers, and mountain goat numbers and sheep numbers suggest that continuation of aggressive population management of elk and goats through hunting is desirable if sheep populations are to thrive.
2. The 2½ years of data collected in this study cover too short a period to indicate transplant success. Managers should continue to monitor survival (winter range classification counts) and reproduction (mid-June lamb counts and winter lamb:ewe ratios) to determine long-term success or failure. Levels of lungworm infection should also be monitored through fecal analysis.
3. If a decision is made to transplant more sheep into the Hilgards, the Quake Lake release site should be avoided. Large snow accumulations, proximity to a major highway, and presence of wintering deer and elk make this a marginal winter range.
4. Winter range vegetation should be monitored yearly for condition and trend, especially as the new population reaches the historical population levels. Range condition should dictate harvest levels.

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APPENDIX

Table 13. Bighorn sheep captured near Thompson Falls and transplanted to Squaw Creek winter range January 28-30, 1988.

Sex	Age at Capture	Radio Collar (RC) or Eartag (ET) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Male	2½	RC - O[b]	153.160	15291[a] 15115		
Male	1½	RC - ♥	153.190	21493 21494		
Male	½	ET - Red =, Red ϕ[a]		21484 21485		
Male	½	ET - Yellow =, Yellow ϕ		21497 21494		
Male	½	ET - Blue ϕ, Yellow O		21499 21500		
Male	½	ET - Blue O, Green +		21449 21450		
Female	6½	RC - +	153.038	15103 15112	P	
Female	6½	RC - white (no symbol)	153.132	15145 15290	P	
Female	4½	RC - /	153.174	21447 21448	P	
Female	4½	RC - ~	153.150	21486 21487	P	

Table 13. Continued.

Sex	Age at Capture	Radio Collar (RC) or Eartag (ET) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Female	4½	RC - ■	153.100	21495 21496	P	
Female	3½	RC - ≻—	153.030	21478 21479	P	
Female	1½	RC - ▭	153.052	21481 15118	P	
Female	1½	RC - ▬	153.022	15293 15272	ND[c]	
Female	ND	RC - ❙	153.082	15274 15276	ND	
Female	ND	RC - ●	153.008	15285 15279	ND	
Female	ND	RC - ▲	153.114	10994 15284	ND	
Female	½	ET - Blue ~, Blue +		15287 15281		
Female	½	ET - Green ~, Green =		21483 21482		

[a] Right ear, left ear. ϕ = blank eartag with no symbol.

[b] White collar with black symbols.

[c] No data.

Table 14. Bighorn sheep captured near Thompson Falls (5) and Anaconda (Lost Creek - 18) and transplanted to Quake Lake winter range January 12-13 and February 8-9, 1989 (respectively).

Sex	Age at Capture	Radio Collar (RC), Ritchey Collar (PC) or Eartag (ET) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Male*	3½	RC - [b]	153.068	A4210[a] A4209		Mort. 2/89
Male*	½	ET - Green ϕ, Green O[a]		A4202 A4201		
Female*	4½	RC -	153.264	A4205 A4206	P	Mort. 3/89
Female*	2½	RC -	153.177	A4207 A4208	NP	Mort. 2/89
Female*	½	ET - Red +, Red ~		A4204 A4203		
Male	1½	RC -	153.587	A4226 A4227		
Male	½	ET - White +, Red O		A4218 A4219		
Female	5½	RC -	153.308	A4241 A4240	P	Mort. 3/89
Female	4½	RC -	153.438	A4229 A4228	P	Mort. 3/89

Table 14. Continued.

Sex	Age at Capture	Radio Collar (RC), Ritchey Collar (PC) or Eartag (ET) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Female	4½	PC - =[c]		A4251 A4252	P	
Female	3½	RC -	153.387	A4222 A4223	P	
Female	3½	RC - ⋈	153.324	A4239 A4238	P	
Female	3½	RC - ☆	153.250	A4234 A4235	P	
Female	3½	PC - ▲		A4246 A4247	P	
Female	3½	PC - >		A4245 A4244	P	
Female	2½	PC -		A4248 A4249	P	
Female	1½	RC - ○	153.530	A4220 A4221	P	Moved to Squaw 5/89
Female	1½	RC - []O[]	153.203	A4236 A4237	ND[d]	Mort. 12/89

Table 14. Continued.

Sex	Age at Capture	Radio Collar (RC), Ritchey Collar (PC) or Eartag (ET) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Female	1½	PC - |●|		A4232 A4233	P	Mort. assumed winter '89
Female	1½	RC - △	153.343	A4242 A4243	P	
Female	½	ET - White ϕ, White ϕ		A4212 A4213		
Female	½	ET - Yellow ϕ, Yellow ϕ		A4215 A4214		

*Thompson Falls sheep transplanted 1/13/89.

[a] Right ear, left ear. ϕ = blank eartag with no symbol.

[b] White collar with red symbol = □.
White collar with black symbol = ■.

[c] Ritchey collars light blue with white symbols.

[d] No data.

Table 15. Native Hilgard bighorn sheep darted and radio collared at Quake Lake winter range, March 8, 1989.

Sex	Age at Capture	Radio Collar (RC) Identification	Radio Freq. (MHz)	MDFWP Eartag Numbers	Preg. (P) Not Preg. (NP)	Comments
Female	3½	RC -◎▬◎[b]	153.209	A4255[a] A4256	P	
Female	7½	RC -□■□	153.401	A4253 A4254	P	

[a] Right ear, left ear.

[b] White collar with red (□) and black (■) symbols.

Table 16. **Blood analysis results (Biochemical and Complete Blood Count) for transplanted sheep from Thompson Falls and Lost Creek and darted Hilgard native sheep. Gardiner and Phillipsburg data are given for comparison.**

Blood Parameters[a]

Sheep Population Source	BUN x̄	BUN min	BUN max	T.Pro. x̄	T.Pro. min	T.Pro. max	Alb. x̄	Alb. min	Alb. max	Ca^+ x̄	Ca^+ min	Ca^+ max	Mg^+ x̄	Mg^+ min	Mg^+ max	Phos. x̄	Phos. min	Phos. max	Na^+ x̄	Na^+ min	Na^+ max
Thompson Falls (N=19)[b]	29.5	19	37	6.2	5.5	7.2	4.6	4.2	5.3	10.2	9.6	10.9	2.1	1.8	2.4	3.0	1.2	5.1	149.2	140	154
Lost Creek (N=19)	13.2	8	21	5.7	5.3	6.5	4.3	3.7	4.9	9.7	9.0	10.5	2.2	1.9	2.8	3.0	1.8	4.5	147.9	145	150
Hilgard Natives (N=3)	14.7	8	20	5.3	5.1	5.4	3.7	3.4	3.9	9.9	9.2	10.5	2.3	2.1	2.4	4.4	2.7	5.3	133.7	126	139
Gardiner[d] (N=14)	12.0	8.7	16.6	7.2	6.1	8.3	4.0	3.4	4.9	10.3	9.2	11.6	2.9	2.2	3.4	5.2	2.9	6.8	153	150	157
Phillipsburg[d] (N=12)	14.5	10.8	20.7	6.1	5.8	6.7	4.1	3.7	4.6	10.3	8.9	11.1	1.5	1.3	2.1	3.5	2.3	5.8	137	144	154

Sheep Population Source	K^+ x̄	K^+ min	K^+ max	Trig. x̄	Trig. min	Trig. max	Alk.P. x̄	Alk.P. min	Alk.P. max	RBC x̄	RBC min	RBC max	MCV x̄	MCV min	MCV max	Hct. x̄	Hct. min	Hct. max	Hgb. x̄	Hgb. min	Hgb. max	WBC x̄	WBC min	WBC max
Thompson Falls (N=19)[b]	9.0	5.8	17.4	53.3	16	259	180.9	44	506	12.1	9.4	13.1	40	36	43	47.6	39.9	50.7	18.4	15.5	20.1	6.8	3.7	10.5
Lost Creek (N=19)	7.3	5.9	10.0	236	112	382	256.7	33	561	9.9	9.2	10.6	42.1	38	46	51.0	46.4	60.0	18.3	17.1	19.6	4.9	2.9	9.3
Hilgard Natives (N=3)	20.0	16.7	22.6	ND[c]			26.7	14	36	11.5	11.0	11.9	41.7	38	44	47.2	43.6	50.3	16.8	16.3	18.0	3.5	3.1	4.0
Gardiner[d] (N=14)	6.7	5.6	9.0	ND			135.4	35	447	12.3	36	42	38.6	36	42	47.1	42.6	53.1	18.8	16.6	21.5	ND		
Phillipsburg[d] (N=12)	6.2	4.5	7.1	ND			266.3	47	499	12.7	10.8	14.3	37.9	35	43	47.6	44.0	55.3	18.9	16.8	20.6	ND		

[a] See Appendix Table 18 for key to blood parameter abbreviations and units of measure.

[b] Thompson Falls 1988 and 1989 data pooled.

[c] ND = No data available.

[d] Gardiner and Phillipsburg data from D. Palmisciano (unpublished data, 1988) MDFWP.

Table 17. Blood serology test results for antibody presence. Number and frequency of Seropositive and Suspect[a] results presented.

Sheep Population Source	Bru. No.	Bru. %	Bt. No.	Bt. %	Ana. No.	Ana. %	L.Pom. No.	L.Pom. %	L.Har. No.	L.Har. %	L.Aut. No.	L.Aut. %	L.Grp. No.	L.Grp. %	L.Ict. No.	L.Ict. %
Thompson Falls 1988, (N=14)	0	0	0	0	2	14.3	1	7.1	0	0	2	14.3	0	0	0	0
Thompson Falls					1	20.0[a]										
1989, (N=5)	0	0	0	0	4	80.0	0	0	0	0	1	20.0	0	0	1	20.0
Lost Creek					3	15.0[a]										
(N=20)	0	0	0	0	0	0	1	5.0	0	0	7	35.0	1	5.0	0	0
Hilgard Natives (N=3)	0	0	0	0	0	0	1	33.3	0	0	1	33.3	0	0	0	0

Serology Test[b]

[a] "Suspect" result - reaction not strong enough for seropositive category.

[b] See Appendix Table 18 for key to Serology Test abbreviations.

Table 18. Key to blood analysis abbreviations and units of measure.

Abbreviation	Parameter	Unit of Measure
Biochemical Test and Complete Blood Count		
BUN	Blood Urea Nitrogen	mg/dl
T.Pro.	Total Protein	gm/dl
Alb.	Albumin	gm/dl
Ca^+	Calcium	mg/dl
Mg^+	Magnesium	mg/dl
Phos.	Phosphorus	mg/dl
Na^+	Sodium	meq/l
K^+	Potassium	meq/l
Trig.	Triglyceride	mg/dl
Alk.P.	Alkaline Phosphatase	IU/l
RBC	Red Blood Cells	# x 106 mm^3
MCV	Mean Corpuscular Volume	um^3
Hct.	Hematocrit	%
Hgb.	Hemoglobin	gm/dl
WBC	White Blood Cells	# x 103 mm^3
Serology Test		
Bru.	Brucellosis	
Bt.	Bluetongue	
Ana.	Anaplasmosis	
L.Pom.	Leptospira pomona	
L.Har.	Leptospira hardjo	
L.Aut.	Leptospira autumnalis	
L.Grp.	Leptospira grippotyphosa	
L.Ict.	Leptospira icterohemorrhagia	

Table 19. Lungworm shedding rates measured in larvae per gram (LPG) of feces of sheep transplanted into the Hilgard study area and native sheep darted and radio-collared.

Lungworm Larvae per Gram of Feces				
Thompson Falls 1988	Thompson Falls 1989	Thompson Falls 1989[a]	Lost Creek 1989	Hilgard Natives 1989
903.5[b]	9.3	600[b]	0[c]	0
211.5	0	350	0	24.2
112.0	1.2	810	0	0.2
498.5	0	110	0	
82.9	13.4	975	0	
400.5		875	0	
79.5		765	0	
366.5		215	0	
168.0		210	0	
150.0		305	0	
298.0		375	0	
155.0		95	0	
209.0		45	0	
74.3			0	
181.7			0	
183.3				
317.1				

[a] Data from Washington State University Veterinary Pathology Lab (unpublished data, 1989). Nineteen sheep trapped together at Thompson Falls in 1989; 5 transplanted to Hilgards, 14 transplanted to Washington.

[b] Fecal samples crushed prior to Baermann procedure.

[c] Fecal samples frozen before analysis - data questionable.

Table 20. Monthly mean temperature (°C), total precipitation (cm), total snowfall and maximum depth on the ground (cm), and departures from normal for 4 weather stations near the Hilgard study area (January 1988-July 1990).[a]

		Temperature (°C)		Precipitation (cm)		Snowfall (cm)	
Month	Station[b]	Mean	Depart.	Amount	Depart.	Amount	Max. Depth
Jan. 1988	E	-6.1	-0.88	0.43	-0.43	[c]	
	HD	-12.2	-0.83	5.23	-3.58	86.36	63.50
	TP	-13.3		6.86		68.6[d]	
	CB	-12.7		9.91		99.1[d]	
Feb. 1988	E	-0.1	+2.0	0.58	-0.28		
	HD	-8.4	+0.1	4.22	-2.24	71.12	78.74
	TP	-9.9		5.59		55.9	
	CB	-8.9		8.13		81.3	
Mar. 1988	E	1.3	+1.3	2.51	+0.86		
	HD	-4.8	+0.7	4.01	-2.29	33.02	76.20
	TP	-7.6		6.60		66.0	
	CB	-8.0		11.94		119.4	
Apr. 1988	E	7.9	+2.7	5.33	+2.77		
	HD	3.1	+2.3	3.28	-1.68	7.62	50.80
	TP	-1.7		8.13		81.3	
	CB	-0.9		12.95		129.5	
May 1988	E	11.6	+1.3	8.81	+3.96		
	HD	9.3	+2.2	4.42	-2.72	0	0
	TP	3.6		4.32			
	CB	3.3		7.37			
June 1988	E	18.2	+3.6	2.74	-3.17		
	HD	15.8	+4.1	2.01	-6.40	0	
	TP	10.8		1.27			
	CB	11.4		1.27			
July 1988	E	20.3	+1.9	0.20	-0.25		
	HD	18.2	+2.2	3.05	-0.97	0	
	TP	13.1		1.27			
	CB	14.0		1.77			
Aug. 1988	E	17.7	+0.3	1.50	-1.47		
	HD	17.0	+1.9	0.53	-4.52	0	
	TP	11.1		0.76			
	CB	12.7		0.76			
Sep. 1988	E	12.0	-0.4	2.24	-1.09		
	HD	11.1	+0.7	1.37	-3.33	T[e]	T
	TP	6.0		3.05			
	CB	6.3		3.56			

Table 20. Continued.

Month	Station[b]	Temperature (°C) Mean	Temperature (°C) Depart.	Precipitation (cm) Amount	Precipitation (cm) Depart.	Snowfall (cm) Amount	Snowfall (cm) Max. Depth
Oct. 1988	E	10.6	+3.0	0.66	-1.63		
	HD	8.8	+4.3	0.05	-4.24	0	0
	TP	3.8		1.52			
	CB	4.5		0			
Nov. 1988	E	0.6	-0.1	2.36	+1.04		
	HD	-3.1	+0.6	12.19	+6.10	149.86	48.26
	TP	-6.9		12.95		129.5	
	CB	-8.3		18.29		182.9	
Dec. 1988	E	-4.4	-1.4	0.63	-0.36		
	HD	-11.2	-1.4	7.24	-1.14	119.38	76.20
	TP	-12.2		7.11		71.1	
	CB	-10.9		7.62		76.2	
Jan. 1989	E	-4.6	+0.6	2.18	+1.32		
	HD	-11.5	-0.2	10.41	+1.60	114.78	101.60
	TP	-12.4		7.87		78.7	
	CB	-12.1		12.70		127.0	
Feb. 1989	E	-10.6	-8.5	0.66	-0.20		
	HD	-12.9	-4.4	4.22	-2.24	71.12	101.60
	TP	-14.5		3.56		35.6	
	CB	-13.2		5.08		50.8	
Mar. 1989	E	0.8	+0.8	2.29	+0.63		
	HD	-3.1	+2.4	9.93	+3.63	127.00	111.76
	TP	-5.8		10.67		106.7	
	CB	-6.3		17.27		172.7	
Apr. 1989	E	6.8	+1.6	2.54	-0.02		
	HD	2.1	+1.3	1.27	-3.68	12.70	99.06
	TP	-1.7		5.33		53.3	
	CB	-1.8		10.92		109.2	
May 1989	E	10.3	0.0	5.97	+1.12		
	HD	7.2	+0.1	5.23	-1.90	0	0
	TP	2.1		6.35			
	CB	1.3		11.18			
June 1989	E	15.3	+0.7	3.53	-2.39		
	HD	12.0	+0.3	5.41	-3.00	0	
	TP	6.9		5.59			
	CB	6.4		8.13			
July 1989	E	20.4	+1.9	2.44	-0.46		
	HD	17.7	+1.6	3.50	-0.51	0	
	TP	12.9		2.54			
	CB	13.8		4.32			

Table 20. Continued.

Month	Station[b]	Temperature (°C) Mean	Temperature (°C) Depart.	Precipitation (cm) Amount	Precipitation (cm) Depart.	Snowfall (cm) Amount	Snowfall (cm) Max. Depth
Aug. 1989	E	16.7	-0.7	5.31	+2.34		
	HD	14.5	-0.6	5.89	+0.84	0	
	TP	11.0		3.81			
	CB	9.2		5.08			
Sep. 1989	E	12.8	+0.4	0.94	-2.39		
	HD	10.4	+0.1	3.10	-1.60	0	
	TP	4.4		2.79			
	CB	5.9		2.79			
Oct. 1989	E	6.9	-0.7	4.29	+2.01		
	HD	3.8	-0.7	5.87	+1.57	33.02	15.24
	TP	0.9		9.65			
	CB	-0.4		10.67			
Nov. 1989	E	2.7	+2.1	1.07	-0.25		
	HD	-2.4	+1.3	4.90	-1.19	40.64	20.32
	TP	-4.4		7.62		76.2	
	CB	-6.5		8.89		88.9	
Dec. 1989	E	-3.7	-0.7	0.91	-0.08		
	HD	-9.8	-0.1	5.74	-2.64	111.76	66.04
	TP	-9.6		6.86		68.6	
	CB	-9.8		7.11		71.1	
Jan. 1990	E	-2.6	+2.6	1.32	+0.46		
	HD	-8.6	+2.7	8.99	+0.18	154.94	71.12
	TP	-8.1		11.68		116.8	
	CB	-10.4		16.26		162.6	
Feb. 1990	E	-2.2	-0.1	0.03	-0.84		
	HD	-9.4	-0.9	4.55	-1.90	76.20	81.28
	TP	-9.8		4.83		48.3	
	CB	-11.3		8.89		88.9	
Mar. 1990	E	1.9	+1.9	2.26	+0.61		
	HD	-3.1	+2.5	3.38	-2.92	55.88	99.06
	TP	-4.3		5.59		55.9	
	CB	-5.8		8.13		81.3	
Apr. 1990	E	7.7	+2.5	4.39	+1.83		
	HD	3.7	+2.9	4.14	-0.81	8.89	48.26
	TP	0.7		6.35		63.5	
	CB	-0.3		9.40		94.0	
May 1990	E	9.3	-1.1	4.95	+0.10		
	HD	6.5	-0.6	7.24	+0.10	T	T
	TP	1.8		8.89			
	CB	0.1		12.7			

Table 20. Continued.

		Temperature (°C)		Precipitation (cm)		Snowfall (cm)	
Month	Station[b]	Mean	Depart.	Amount	Depart.	Amount	Max. Depth
June 1990	E	14.8	+0.3	3.61	-2.31		
	HD	11.7	-0.1	5.64	-2.77	0	0
	TP	7.3		8.64			
	CB	6.2		6.86			
July 1990	E	18.7	+0.3	3.18	+0.28		
	HD	16.4	+0.4	2.41	-1.60	0	
	TP	11.6		2.29			
	CB	12.0		2.54			

[a] Data from the National Oceanic and Atmospheric Administration (NOAA) 1988-1990, (E and HD). Data from the Soil Conservation Service Snow Survey Unit, Bozeman, MT 1988-1990, (TP and CB).

[b] E = Ennis, HD = Hebgen Dam, TP = Taylor Peaks, CB = Carrot Basin.

[c] Snowfall data missing from this station.

[d] Taylor Peaks and Carrot Basin are automated Snow Pillow sites; monthly snowfall totals are approximate.

[e] T = Trace.