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Aspects of bald eagle winter behavior in Rush Valley Utah: A Telemetry study

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Aspects of Bald Eagle Winter Behavior in Rush Valley Utah: A Telemetry Study

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by
Neil B. Sabine

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This manuscript, by Neil B. Sabine, is accepted in its present form by the department of Zoology of Brigham Young University as satisfying the dissertation requirement for the Degree of Doctor of Philosophy.

11 Dec 87
Date

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ASPECTS OF BALD EAGLE WINTER BEHAVIOR IN RUSH VALLEY UTAH: A TELEMETRY STUDY

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ABSTRACT

Diurnal behavior and nocturnal roosting patterns were investigated in a population of 200 - 300 bald eagles wintering in Rush Valley, Utah. The activities of 28 individuals outfitted with tail-mounted radios were monitored for over 1600 hrs between January and March 1982-1984. Average home range size was 960 km^2 but perching patterns suggested habitual use of small areas of diurnal habitat. During the day, most eagles perched on the ground and seldom used perches higher than junipers. Casting analysis and feeding observations indicated the principal food source was jackrabbit carrion. Jackrabbit availability declined from 1982 to 1984 and eagles responded by; 1) roosting closer to feeding sites, 2) shifting from canyon to valley roosts, 3) arriving later at and departing earlier from roosts, 4) decreasing diurnal activity, and 5) decreasing residence time. Foraging efficiency appeared to be maximized by experienced eagles using familiar feeding areas and by naive birds monitoring their activity. Canyon roosts were dominated by Douglas Fir, White Fir, and Pinyon Pine; valley roosts were composed of willow. Roosts closest to foraging areas were preferred. There appeared to be a slight (8.6%) energetic advantage to roosting at valley sites because of their proximity to feeding areas. This saving was presumably lost under adverse weather conditions when eagles selected the sheltered microclimate of canyon slopes. Twelve eagles were tracked during spring migration and all followed northward routes; 3 were found nesting near Great Slave Lake, NWT.

INTRODUCTION

The bald eagle (Haliaeetus leucocephalus) is the only indigenous representative of the sea and fish eagles in North America (Grossman and Hamlet 1964). Population declines during the 1960's prompted extensive studies on bald eagle life history. Nesting and food habit studies were first investigated (King et al. 1972, Sprunt et al. 1973, Weekes 1975, Leighton et al. 1979) to determine factors responsible for this decline.

Determination of the effects of environmental contaminants on bald eagles was an outgrowth of food habits studies. High pesticide levels have contributed to decreased reproduction due to eggshell [illegible]ng (Hickey and Anderson 1968, Krantz et al. 1970, Grier 1974). Subsequent bans on the use of these chemicals and implementation of management programs (Snow 1973, Mathisen et al. 1977) are methods used in an attempt to stabilize populations. The Endangered Species Act (1973) protected the bald eagle in most states and thereby increased their federal protection.

Most bald eagles nest in Canada and Alaska and begin to move south in autumn, probably in response to reduced prey availability. Eagles congregate at wintering areas, principally in the midwest and west, that offer a dependable source of food and provide acceptable habitat. Nearly 13,000 eagles winter in the lower 48 states (Grier et al. 1983) and 3,000 to 4,000 of these are found west of the Rocky Mountains (Gerrard 1983).

Habitat alterations at the relatively few remaining areas where wintering eagles congregate could have significant impacts on reproduction. Preservation and management of winter habitat, therefore, should be based on an understanding of the critical characteristics of areas used by bald eagles.

Being principally piscivorous, most wintering populations are found along coasts (Larson and Abbott 1962, Hancock 1964, Retfalvi 1965), lakes (Johnson 1961, Nye 1977, Griffin 1978, Russell 1979), and rivers (Southern 1963, 1964; Vian 1971, Jonen 1973, Servheen 1975, Stalmaster 1976, Steenhof 1976, Sabine 1982, Harmata 1984). These areas supply a dependable source of food and provide acceptable habitat for feeding and roosting throughout the winter.

Eagles in the West winter in 2 general habitat types. Riparian areas are most commonly used (Swisher 1964, Shea 1973, Stalmaster 1976, Pannetier 1980, LaBonde 1981, Keister 1981) where waterfowl and fish are the main staples in the eagle's diet. A few populations spend most of their wintering period at upland sites (Imler 1937, Edwards 1969, Swenson et al. 1981, Harmata 1984) and feed principally on mammalian carrion. Most management guidelines have been developed for populations in riparian habitat (Lish 1973, Shea 1973, Forbis 1975, Stalmaster 1976, Griffen 1978, Steenhof 1976) and may not be applicable to wintering grounds in more arid areas.

A population of 200-300 bald eagles winters in the arid valleys of north-central Utah (Edwards 1969). Eagles are apparently attracted to the area by the large number of black-tailed jackrabbit (<u>Lepus californicus</u>) carcasses left by recreational hunters (Platt 1976).

The origin of this population is uncertain. The earliest documented sighting was of 20 eagles flying in south Cedar Valley on

24 December, 1960 (Bee 1960). Based on this and interviews with local ranchers, Edwards (1969) believed that the formation of this concentration occurred recently. An alternate hypothesis is advanced by Joseph (1977) and Murphy (1977) who propose that part of the wintering population are descendants of eagles that nested there during the Pleistocene, when Lake Bonneville covered the area. Regardless of origin, the growth in size of the population wintering in Rush Valley is recent and is probably related to prey availabilty.

Edwards (1969) conducted the first field study on bald eagles wintering in central Utah. He was principally concerned with population size, location of roosts and feeding sites, and food habits. Joseph (1977) investigated age class structure and feeding and roosting behavior. Habitat selection, foraging behavior, home range size, roosting patterns, and migration routes remain poorly understood.

Biotelemetry provides detailed empirical data on eagle behavior which could not be obtained otherwise. From January 1982 to May 1984 characteristics associated with bald eagle behavior and habitat use were investigated, principally by radio-tracking 30 individuals. It is hoped that this information will be useful in developing management guidelines for the bald eagle in north-central Utah.

Objectives of the study were to:

1) determine the relative importance of roosting and feeding areas,
2) investigate environmental factors which may influence the selection of roosting and feeding sites,

3) examine and relate daily/seasonal patterns of behavior and dispersal to habitat utilization,
4) locate previously unknown areas of eagle use,
5) describe northward movements of eagles to their summering grounds, and
6) propose bald eagle management guidelines to resource and land management agencies.

STUDY AREA

Three broad arid valleys in central Utah lie on the eastern edge of the Great Basin physiographic province. Rush Valley, located 60 km southwest of Salt Lake City, is the principal study area (Figure 1). Its gently sloping floor is bordered to the east, south, and west by mountains and elevations range from 1520 m on the valley floor to 3309 m at mountain peaks.

Parallel north-south trending mountain ranges divide the valleys. The eastern border is Lake Mountain in Cedar Valley and Dugway Proving Grounds in Skull Valley borders to the west.

Mean annual precipitation varies from 26 cm in desert lowlands to 127 cm at higher elevations. Mean temperatures range from 0 C to 34 C and daily temperatures fluctuate widely. During the winter, snow cover is sporadic at lower elevations but is several feet deep along mountain ridges. With the exception of a few small reservoirs and springs, no permanent bodies of water exist within Rush Valley.

The desert shrub community of lower elevations is typified by big sagebrush (_Artemesia_ _tridentata_), shadscale (_Atriplex_ _confertifolia_), rabbitbrush (_Chrysothamnus_ _nauseosus_), greasewood (_Sarcobatus_ _vermiculatus_), winterfat (_Eurotia_ _lanata_), and cheatgrass (_Bromus_ _tectorum_) (Foster 1965). Grazing by wintering sheep has severely impacted native lowland vegetation; halogeton (_Halogeton_ _glomeratus_) and russian thistle (_Salsola_ _kali_) have replaced native species and cheatgrass has increased in dominance. Utah juniper (_Juniperus_ _osteosperma_) and pinyon pine (_Pinus_ _monophylla_) are common in the

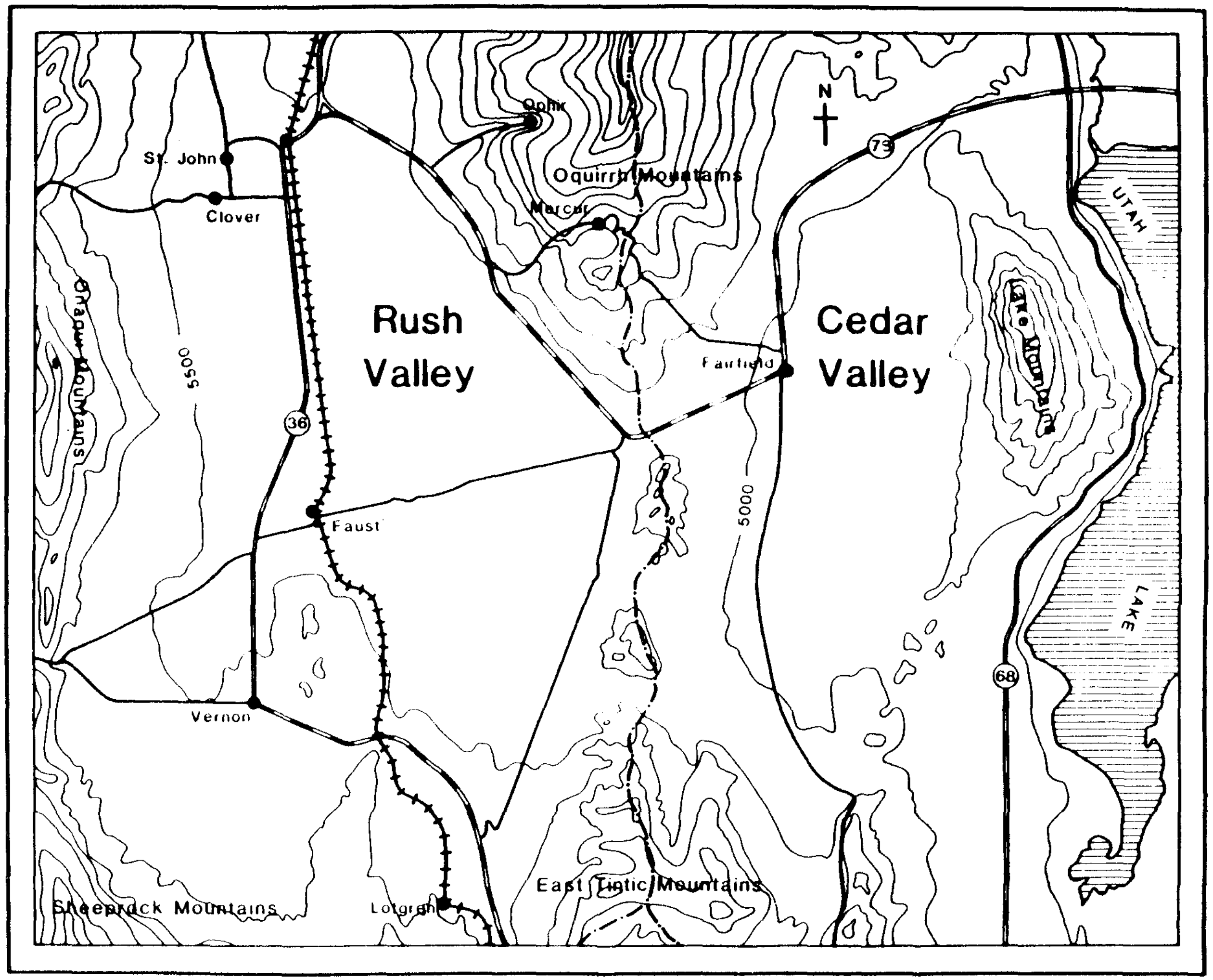

Figure 1. Map of principal study area in central Utah.

foothills, and montane forests of fir (Abies spp.), spruce (Picea spp.), Douglas fir (Psuedotsuga menziesii), and aspen (Populus tremuloides) dominate higher elevations. Edwards (1969) provides a detailed description of the major vegetative communities in Rush Valley.

The south section of Tooele Army Depot occupies 76 km^2 in northcentral Rush Valley. Two highways provide access to the compound from the east and west and a railway, along the depot's western border, bisects the valley. Over 9,300 sheep graze in the area and most activity involves moving these animals between allotments. During mild winter weather, recreational hunting is common on weekends.

METHODS

Trapping and Handling

Patterns of winter habitat use were principally determined by monitoring a sample of radio-tagged eagles captured near Vernon, Utah. Eagles were trapped using a modified version of the Lockhart method (Miner 1975). Traps were #3 leg-holds (Victor Animal Trap Co., Oneida, NY) with leather-padded jaws and detempered springs.

Jackrabbit carcasses were primarily used as bait and 2 traps, 1 close to the belly and the other near the back, were concealed under dirt or snow. The 2 traps were connected with a 1 kg weight wired to stake down chains to insure all trapped birds were incapable of flight. A sheep carcass was used on 3 occasions and, because of its large size, 2 additional traps were placed near the head and tail.

Traps were placed near consistently used perch sites or in large open areas which were believed to have been easily seen by flying eagles. Sets were laid as outlined by Harmata (1984) with the following modifications: 1) plywood pads 0.3 m square and 0.9 cm (3/8 in) thick were placed under traps; 2) no lure birds were used; and 3) sets were made between 0300 Hr and 0600 Hr and were retrieved after 1630 Hr.

Captured eagles were usually approached slowly on foot from the rear by 2 individuals. Hooding, generally with a coat, was done first as this appeared to calm birds. The eagle was then secured by 1 individual gently folding the wings against the body while the other grabbed both feet. The wings were then tied firmly against the body using a triangular cloth (Young 1983) and the trap was removed.

Lastly, the eagle was wrapped in a wool blanket and driven to an indoor processing center.

Radio transmitters (Telonics Inc., Mesa, AZ) were placed on the dorsal surface of the 2 central rectrices of captured eagles. Transmitter dimensions and mounting procedures were identical to those discussed by Young (1983). The 50 - 55 gm transmitters had life expectancies of 5 months and utilized frequencies between 148.00 and 165.99 MHz. Some birds were additionally marked by snipping a 15-20 cm section from the third and fourth primaries which helped identify them in flight (Enderson 1960).

Eagles were fitted with aluminum leg bands, weighed, and measured. Measurements included talon, tarsus, wingchord, and culmen lengths. Bald eagles with a completely white head and tail were considered adults and all others were considered immatures. Sex was determined by culmen length (Harmata and Stahlecker 1977). Energy reserves were subjectively assessed by palpating fat deposits below the sternum; reserves were assigned a value between 0 (lean) and 5 (fat).

Monitoring

Instrumented eagles were monitored by 2 independent tracking teams. One team was staffed by members of the Bureau of Land Management, U.S. Fish and Wildlife Service, and the Utah Department of Wildlife Resources; the other employed the author. Systematic sampling of marked birds was a compromise between funding constraints and statistical considerations for data analysis. The wide ranging movements of eagles often led to schedule revisions and most monitoring time was spent on birds roosting in Rush Valley. All frequencies, however, were scanned each morning and evening with priority given to tracking those eagles with the most time elapsed from their previous tracking dates.

Each day, trackers began monitoring at least one-half hour before sunrise and ceased when the eagle entered its evening roost. Attempts were made to maintain visual contact with marked birds all day but this was influenced by weather conditions, topography, and eagle behavior. If visual contact was lost, locations were first determined from a vehicle using a radio receiver (Telonics TR-1 or TR-2), a omni-directional (Omni) antenna, and a hand-held, directional (Yagi) antenna. Visual contacts were reestablished with a variable power (15 - 60 x) spotting scope and binoculars (7 x 35). During each observation, information on perch type, habitat class, number and ages of conspecifics, and eagle behavior was recorded on standard data forms.

Distances were difficult to estimate over the relatively featureless desert terrain so a grid system was used to record the locations of perched eagles. All eagle sightings were placed in 0.28 km^2 squares which were coded as five digit coordinates. Telemetery locations of unsighted radioed eagles had variable grid sizes whose areas were minimized by triagulation and attempts to establish visual contact.

Home Range

Home ranges were calculated using the maximum polygon area technique (MPA) (Marquiss and Newton 1981). This estimate was subject to bias with small samples so only birds monitored for more than 9 days and having a minimum of 20 locations had their home ranges calculated. Marquiss and Newton (1981) reported that MPAs did not differ markedly after 4 - 7 d of monitoring european sparrowhawks (Accipiter nisus).

Diurnal Behavior

Activity. Eagle behavior was divided into perching and flying.

Harmata (1984) defined activity among bald eagles wintering in San Luis Valley, CO, as the percentage of the total monitoring time that an eagle was in flight or on the ground. Since most eagles perched on the ground in Rush Valley, activity was restricted to the percentage of time eagles flew. Signal reception was influenced by line of sight distances between transmitters and receivers. Those from flying eagles were unobstructed by topographic features and were transmitted over greater distances than those from perched birds. Total monitoring time was therefore replaced with the sum of time where the beginning and end of a monitored activity (e.g., perching or flying) were known.

Monitoring time was divided into hourly intervals from 0700 Hrs to 1900 Hrs. For each hour, per cent activity was calculated by dividing the total time spent flying by the total time monitored and then multiplying by 100 (Harmata 1984). The sums of perch and flight times for each hour were used to determine activity levels for various subgroups (adult, female, etc.) of eagles.

Perch Behavior. Perch types were classified as deciduous tree, juniper, telephone pole, fencepost, and ground. Locations and types of perches were obtained by monitoring marked birds and by chance observations of unmarked birds. Observations of radioed and nonradioed birds were analyzed separately and the differences were compared to determine if data from both sources could be pooled. Perch durations were based exclusively on the adjusted times of marked birds.

Flight Behavior. All aspects of flight behavior were based on adjusted times of radio-tagged bald eagles. Flight distances were measured along straight line paths drawn between 2 sequential perch locations. Flight duration was the time spent flying between these points and flight speed was computed by dividing distance by time.

Soaring was not separated from flapping flight because these 2 locomotor modes were used so frequently together. Some soaring was typically used in flights over 10 min but the amount was influenced by weather conditions and destination. All flights to and from canyon roost sites were dominated by soaring, while those to valley roosts were nearly always restricted to direct flapping flights. Lastly, most trackers could not maintain visual contact with flying eagles for any extended length of time during monitoring periods.

Habitat Use. Characteristics associated with habitat selection were determined by comparing areas of use and nonuse. Forty-nine 0.28 km^2 squares with more than 5 bald eagle sightings were compared to 100 random locations of the same size in Rush Valley. U.S. Geological Survey topographic maps (7.5 min series) were used to assess the physical features of each area and data were collected on range of elevation, slope direction, and the number of hilltops and roads. Possible impact of human activity was inferred by further classifying roads by surface materials (e.g., paved, gravel, dirt). General physical characteristics surrounding each site were determined by repeating these same measurements in a 1.6 km^2 square centered on the original site.

Importance of Diurnal Habitat. Importance values were calculated for each quarter (14.4 km^2) of each range with elevations below 1750 m in Rush Valley. Importance values were based on the locations of all perched eagles and the perch durations of marked eagles. The number of eagle sightings in Cedar Valley and Skull Valley was insufficient for these calculations and had to be eliminated from analysis.

Importance values were determined by:

Relative Sightings:

$$\frac{\text{Number of sightings in area X}}{\text{Number of sightings in all areas}}$$

Relative Duration:

$$\frac{\text{Perch time in area X}}{\text{Perch time in all areas}}$$

Importance Value:

$$\frac{(\text{Relative Sightings + Relative Duration})\ 100}{2}$$

Three main biological assumptions expressed by calculating importance values were: 1) sites with many observations were more important to eagles than those with few observations; 2) sites with high perch durations were more important to eagles than those with low values; and 3) the behavior of marked eagles typified those of the wintering bald eagle population.

Nocturnal Behavior

Vegetative Analysis of Roosts. Roosts were located by investigating sites described by Edwards (1969) and by tracking radio-tagged eagles at night. Roost sites are defined as areas where marked eagles perched for at least 3 nights. Major roosts were those used during each year of the study and minor roosts were used only during 1 year. Trees with castings, excrement, or eagle feathers beneath them were considered roost trees.

Species composition and community structure of dominant vegetation of 5 canyon and 3 valley roosts were analyzed. Canyon roosts were systematically sampled using 0.07 ha circular plots along ects laid perpendicular to the roost's slope. The number of and distance between plots for each roost was determined using species area curves (Brower and Zar 1977). Species, diameter at breast height(DBH), age structure (Keister and Anthony 1983), and height were recorded for all trees more than 7 cm DBH within each plot. The slope and aspect of canyon roosts were also measured. Measurements were made using a rangefinder, DBH tape, and Abney level. Valley roosts were under 2 ha in size and all trees in these areas were considered to have been used for roosting.

Roost Behavior. Attempts were made each night to locate the roosts of as many marked eagles as possible. All frequencies were scanned at roosts for monitored birds at the beginning and end of each day. Eagles located at roosts past 1600 Hrs were considered to spend the night there. Periodic inventories of additional roosts were conducted when time and money permitted.

Roost departure and arrival times were recorded. To compensate for varying daylengths with the advance of winter, departure and arrival times were subtracted from sunrise and sunset times, respectively. Distances and durations to and from roosts used by radio-tagged bald eagles were also determined when possible.

Importance of Roosts. Roost preference was determined by calculating an importance value for each roost. Importance values were based on the number of marked birds using a roost at least once (relative frequency) and the total number of marked birds recorded there (relative sightings) during each year. It was believed that roosting patterns of marked birds were characteristic of the wintering population as a whole.

Computations for calculating importance values were:

Frequency:

$$\frac{\text{Number of marked birds using Roost X at least once}}{\text{Number of marked birds using all roosts at least once}}$$

Relative Frequency:

$$\frac{\text{Frequency of Roost X}}{\text{Sum of all roost frequencies}}$$

Relative Sightings:

$$\frac{\text{Number of sightings at Roost X}}{\text{Number of all roost sightings}}$$

Importance Value:

$$\frac{(\text{Relative Frequency} + \text{Relative Use})\ 100}{2}$$

Food Habits

Prey. Bald eagles are believed to feed principally on jackrabbits in Rush Valley (Edwards 1969, Platt 1976). The use of prey items by wintering eagles during this study was determined by investigating carcass remains where eagles fed and by analyzing castings (regurgitated indigestible prey remains) collected beneath roost trees (Errington 1932). Mammalian and avian remains were identified by guard hair (Stains 1958) and contour feather characteristics, respectively, in conjunction with other casting material (bones, skin, etc.). Only complete castings were collected and each was believed to represent on prey individual unless 2 taxa were identified. Casts were collected during March and July for valley and canyon roosts, respectively.

The influence of prey availability on habitat use was examined by walking 28 prey transects on 14 study plots during March 1983 and 1984. Ten plots were randomly selected on the valley floor and 4 were in areas consistently used by bald eagles. Jackrabbit abundance was determined by counting the number of rabbits seen along 2 0.80 km transects in each plot. Counts were made between 0900 Hr and 1600 Hr on 3 randomly selected dates and times. Carcass availability was assessed by counting prey remains seen along each transect during the first census of each year. Subjective assessments of rabbit numbers were made each January during hunts to secure bait, and supplemented transect estimates of jackrabbit abundance.

Feeding Behavior. Feeding bouts of all eagles seen during tracking were recorded. Eagles perched within 200 m of carcasses were considered part of feeding groups. Bald eagles were separated into adult and immature age classes but distinction in the ages of golden eagles (*Aquila chryseaetos*) could not be reliably determined. Social interaction between marked birds and other bald eagles were recorded anecdotally; such records included data on supplanting frequencies, feeding durations, number of conspecifics, and golden eagles present.

Identification of prey remains was considered secondary to monitoring eagle behavior. The distance necessary to minimize eagle disturbance was usually too far to allow prey identification. Carcasses were identified when possible but most remained unknown due to tracking considerations.

Flight distances and durations to and from feeding sites were determined when possible. The influence of roost and perch locations on foraging behavior was also investigated.

Climatic Factors

A Winter Severity Index (Picton and Knight 1971) for each winter was calculated and used to investigate the possible influence of weather on eagle behavior. Data for minimum and maximum daily temperatures were recorded at Vernon, Utah, and snow cover was recorded at Tooele, Utah. Weather data were obtained from Climatological Data Monthly Summary Sheets distributed by the National Oceanic and Atmospheric Administration, Asheville, NC 28801.

Migration

Eagles leaving the study area were first tracked by vehicle. Funding permitted occasional trips to northern Utah and Idaho during 1982 and 1983. In an attempt to identify movements of marked birds to areas outside Rush Valley, the Utah Divison of Wildlife Resources flew 3 inventories in the north central portion of the state during 1982 and 1983. These flights were conducted in a Cessna 185 II airplane at an altitude of 360 m, a flight speed of about 250 km/hr, and each covered over 1200 air km. Possible frequencies were continually scanned while airborne and attempts were made to locate the general area (within 2 - 4 km^2) of marked birds. Movement of eagles into more northern states and Canada was documented by a survey team led by Dr. Riley McClelland from the University of Montana.

RESULTS

Trapping

Twenty-eight bald eagles (Table 1) were captured near Vernon, Utah (Figure 2) during January 1982 - 1984. Fourteen males and 14 females were captured; 7 were immatures. The percentage of trapped adults (73%) approximated their estimated proportion (65%) in the population (Edwards 1969, Joseph 1977) suggesting that each age class was proportionately represented in the trapping sample.

Young (1983) has followed eagles radio-tagged in Glacier National Park, MT, to their wintering grounds in Rush Valley. Each year at least 3 attempts per week were made to locate these birds during roost inventories. In 1982, an adult female and an immature female entered the study area during January and were integrated into the tracking schedule through the remainder of the year. Two additional birds passed through during late March 1983 but remained for only a few days. No eagles marked outside Rush Valley were located during 1984.

All eagles were trapped at sites which used jackrabbit as bait. A sheep carcass attracted only golden eagles and took 8 days before it was first fed upon. Eagles typically landed directly on sheep carcasses which further confounded trapping efforts. A mule deer (<u>Odocoileus</u> <u>hemionus</u>) carcass also failed to attract bald eagles in 1982 and was not used by any raptors for over 3 wks. Deer were probably not a common food source and the tough hide may have discouraged eagles from feeding on them.

Table 1. Trapping data summary for bald eagles captured in Rush Valley, Utah, 1982-1984.

Eagle	Age	Sex	Weight (kg)	Condition[a]	Capture Date
			1982		
AM04	Adult	Male	3.9	5	17 January
AF06	Adult	Female	5.2	5	13 January
IF08	Immature	Female	4.5	4	19 January
IF27	Immature	Female	6.1	5	15 January
IM29	Immature	Male	4.5	NA[b]	14 January
AF34	Adult	Female	5.5	5	19 January
AM36	Adult	Male	4.4	5	13 January
			1983		
AM05	Adult	Male	4.4	3	28 January
AM07	Adult	Male	4.0	2	28 January
AM29	Adult	Male	5.1	4	21 January
IF57	Immature	Female	5.3	3	11 January
AF92	Adult	Female	5.8	4	13 January
AM94	Adult	Male	4.0	5	14 January
AM96	Adult	Male	4.7	5	14 January
			1984		
AF03	Adult	Female	4.9	2	4 January
AF09	Adult	Female	4.9	2	4 January
AF13	Adult	Female	NA	3	5 January
AM17	Adult	Male	4.3	3	6 January
IM24	Immature	Male	4	1	5 January
IF28	Immature	Female	5.0	4	4 January
AM55	Adult	Male	4.1	2	30 December[c]
AM60	Adult	Male	4.0	3	2 January
AF65	Adult	Female	NA	3	3 January
AF70	Adult	Female	5.0	4	28 December
IM73	Immature	Male	4.1	3	29 December
AM75	Adult	Male	4.0	2	30 December
AF95	Adult	Female	4.0	2	30 December
AF97	Adult	Female	4.4	1	30 December

[a] subjectively classified by assessing fat deposited below the sternum; 1 (thin) to 5 (thick)

[b] data not available

[c] 1983

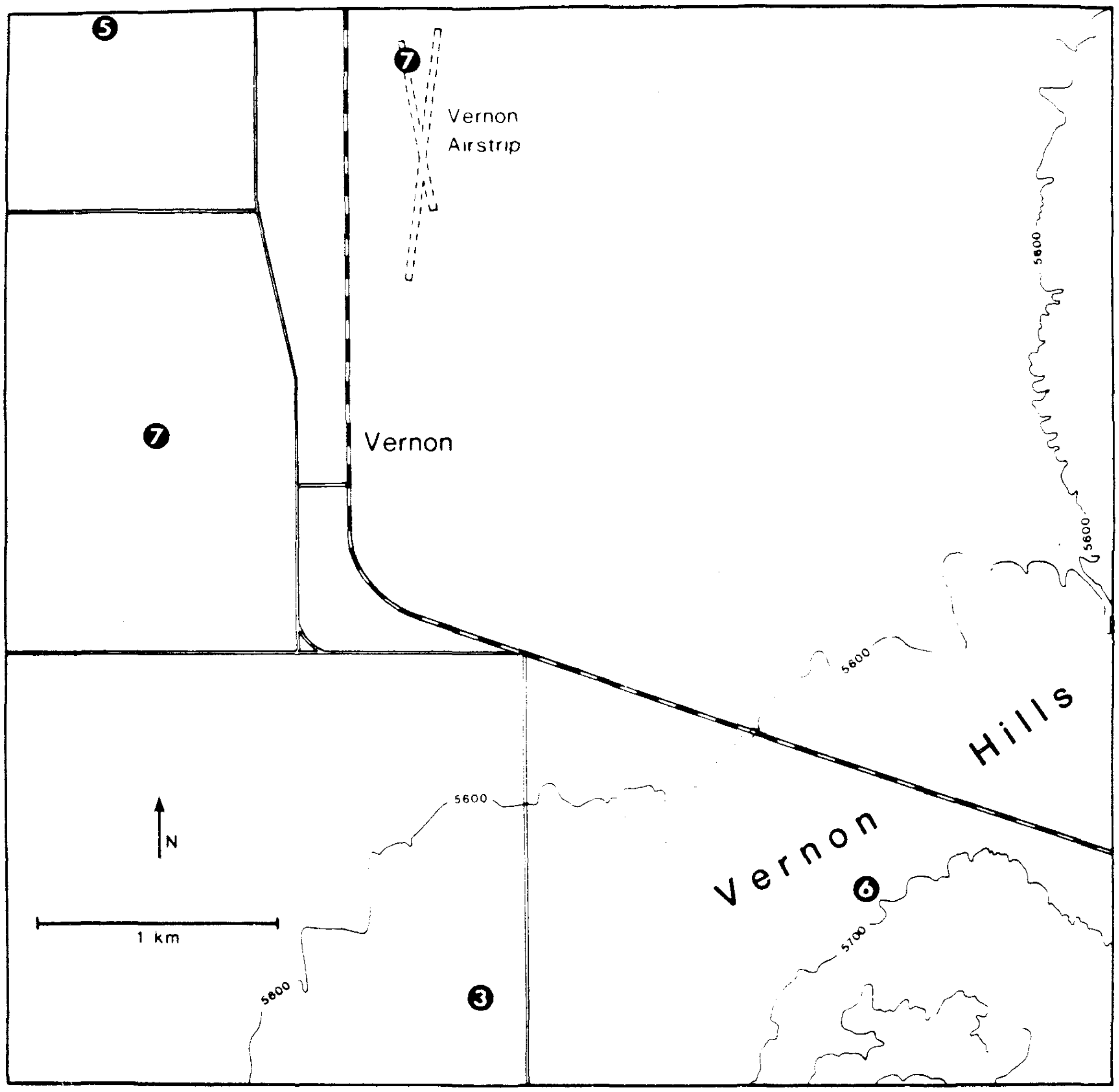

Figure 2. Locations of Bald Eagles captured near Vernon, Utah, January 1982 - 1984. Numbers represent number of eagles captured at each site.

Eagles were typically caught by 1 or 2 toes and all were captured in traps concealed by snow. Carcasses were probably more visible to foraging eagles against a background of snow than against bare earth. The success of traps placed in snow was dependent upon prevailing weather conditions. Ideal conditions followed storms which left 7-10 cm of fresh snow. This covered other carcasses in the area and permitted traps to be well hidden without affecting their performance. On extremely cold days snow above traps crusted and made them ineffective while snow melt on warm days exposed traps which were then avoided.

Although all eagles appeared to be in good physical condition when captured, the amount of fat deposited below the sternum was significanty less in eagles captured in 1984 than in those from 1982 and 1983 (Mann Whitney, $p < 0.01$). It appeared that eagles foraged continually throughout the day, as no differences in trapping success were noted between morning, midday, and afternoon (Chi Square, NS). No injuries associated with trapping were evident on any individual and none were inferred through subsequent monitoring.

Five golden eagles, 5 northern harriers (Circus cyaneus), 9 rough-legged hawks (Buteo lagopus), 1 ferruginous hawk (Buteo regalis), and 8 raven (Corvus corax) were captured by sets intended for eagles during the study. Problems associated with trap placement and weather conditions accounted for most of the captures, but ravens could have been particularly vulnerable because of their consistent association with feeding eagles.

Monitoring and Residency

Telemetry data were collected on 24 of the 30 marked eagles (28 captured in Rush Valley and 2 from Glacier National Park, MT) located during the study period. The remaining 6 individuals were neither seen nor monitored after release and presumably were captured during migration. Eagles remaining in the study area had variable monitoring periods ranging from 3.8 hrs to 211.2 hrs and monitoring time varied between years (Table 2).

After release, marked eagles remained for an average of 45 d (N = 22). Residence durations were between 10 and 80 d (Figure 3) which suggested that any trauma that may have occurred during trapping and handling was not sufficient to cause many eagles to leave the valley. Most (71%) radio-tagged individuals stayed for 30 d and many (38%) were still present after 60 d. Eagles were captured during different times each year in January but capture dates appeared to have no significant effect on residence durations ($r = -0.009$).

A mean departure date of 22 February coincided with the population decline phase for bald eagles wintering in Rush Valley (Edwards 1969, Joseph 1977). There were significant differences between years, however, (ANOVA, $p < 0.001$) with eagles leaving earlier in 1984 than either 1982 or 1983 (Scheffe test, $p < 0.05$). No differences in departure dates were noted between sex and age classes (Mann Whitney, NS). Mean departure dates between fat (classes 4 and 5) and lean (classes 1 and 2) did not differ (Mann Whitney, NS). Departures were believed to have been associated with either intra-range movements or migration. In 1982, most eagles (67%, N = 9)

Table 2. Monitoring data summary for Bald Eagles wintering in Rush Valley, UT, 1982 - 1984.

			Monitoring Time (hrs)			
ID	Time^a	Days Tracked	Flight	Perch	Roost	Total
			1982			
AF06	30	5	8.6 (13)^b	7.5 (8)	32.5(20)	48.6 (41)
IF08	37	4	7.2 (7)	17.8 (6)	16.2(18)	41.5 (31)
IF21^c	63	8	7.8 (13)	1.2 (2)	42.6(32)	51.6 (47)
IF27	11	1	0.9 (4)	1.4 (2)	1.5 (7)	3.8 (13)
IM29	38	3	12.5 (11)	4.7 (7)	9.0(15)	26.2 (33)
AF34	40	10	22.9 (31)	15.2 (18)	29.9(27)	68.0 (76)
AM36	79	12	18.8 (40)	21.3 (23)	31.5(27)	71.6 (90)
AF50^c	71	10	17.4 (29)	19.9 (18)	51.7(39)	89.0 (86)
			1983			
AM05	59	5	5.4 (15)	5.4 (8)	45.0(12)	55.8 (35)
[illegible]	12	4	5.7 (10)	4.5 (6)	24.6 (9)	34.8 (25)
[illegible]	76	21	41.8 (96)	56.1 (77)	74.4(36)	172.3(209)
AF92	75	21	59.4(125)	101.1(149)	50.7(29)	211.2(303)
AM96	19	4	6.7 (24)	17.8 (21)	16.1 (6)	40.6 (51)
			1984			
AF03	57	13	12.3 (92)	105.1 (79)	34.7(46)	152.1(217)
AM09	10	4	7.4 (14)	17.4 (11)	19.1(10)	43.9 (35)
IM28	39	1	3.8 (18)	12.7 (16)	3.5 (2)	20.0 (36)
AM60	42	13	16.2 (65)	46.5 (58)	32.8(29)	95.5(152)
AF65	28	6	13.6 (30)	20.6 (25)	8.7(16)	42.9 (71)
AF70	75	20	23.4(157)	132.4(146)	49.3(52)	205.1(355)
AM75	56	10	11.3 (69)	54.4 (62)	21.2(20)	86.9(151)
AF95	38	5	4.0 (43)	41.4 (40)	7.4(14)	52.8 (97)
AF97	40	2	4.0 (13)	10.7 (12)	0.0 (4)	14.7 (29)

[a] number of days from capture date to last monitored date

[b] number of observations

[c] trapped in Glacier National Park, MT

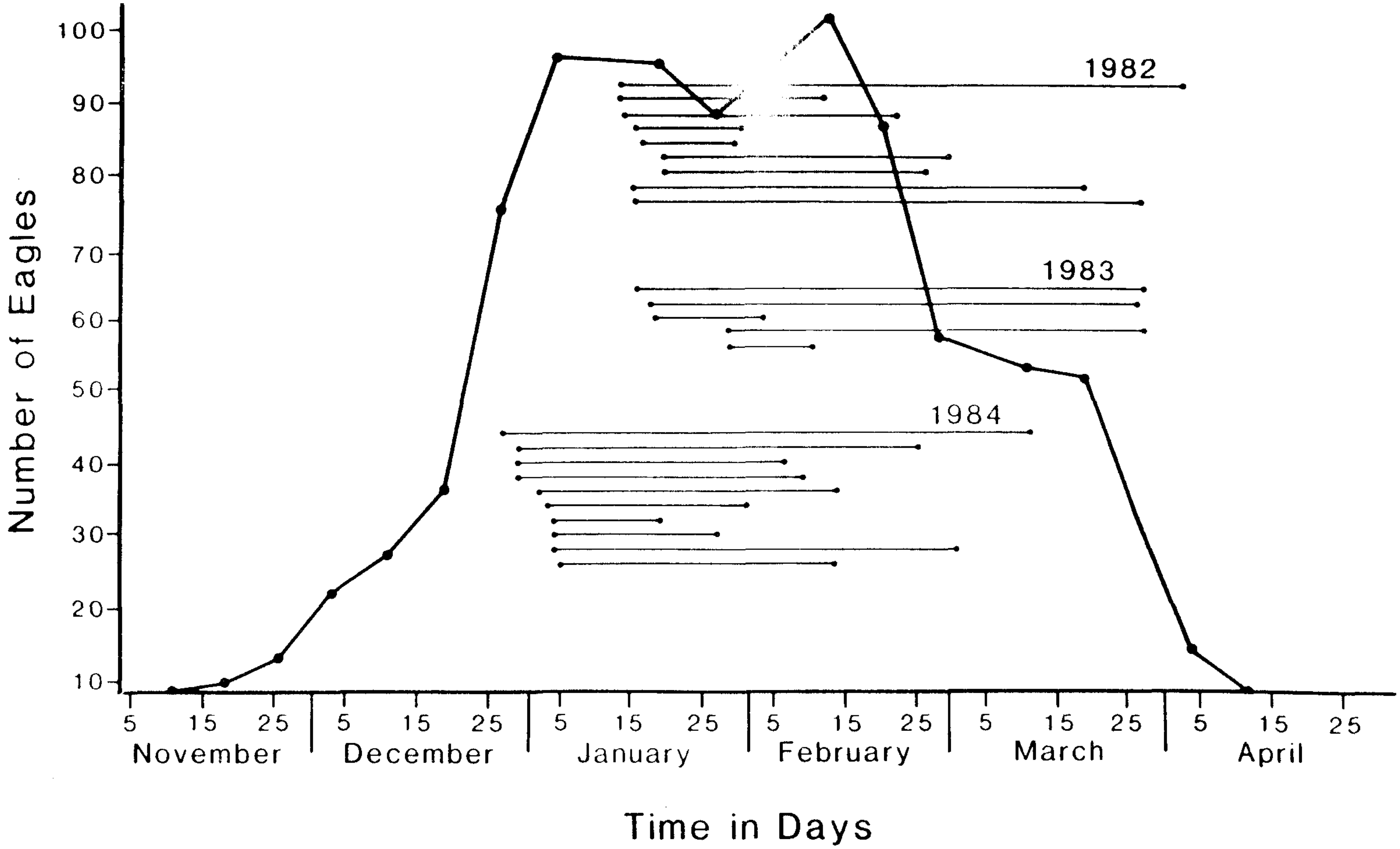

Figure 3. Population dynamics and residencies of transmitter-equipped Bald Eagles monitored in Rush Valley, UT.

left the study area during the population decline phase (Figure 4) and these departures were probably associated with spring migration. In 1983 and 1984, fewer birds (43%, N = 7 and 36%, N = 14) left during this period, which suggested that more eagles in these years may have moved to other wintering areas. Eagles that remained in Rush Valley during 1983 and 1984, however, appeared to be able to meet their energy demands in spite of low jackrabbit numbers (see Food Habits) since there were no significant diffences in residence times between these years and 1982 (Kruskal Wallis, NS).

Four bald eagles were found dead during the study, all during 1984. Three radio-tagged birds presumably died of malnutrition during spring migration (McClelland, pers. comm.). These eagles remained in Rush Valley for short periods of time and may not have been able to compete against more experienced residents. The fourth was not marked and was found beneath a canyon roost tree.

Home Range

Maximum area polygons were constructed by connecting the outermost locations of diurnal perches and roost sites. Home ranges were calculated for 9 eagles who met the minimum of 10 tracking days and 70 hrs monitoring time (Table 3).

The average home range size was 960 km^2 and varied from 611 km^2 to 1518 km^2. Kruskal Wallis analysis showed no significant difference in home range sizes between years. Home range dimensions were also similar between males and females (Mann Whitney, NS). Only 1 of the 9

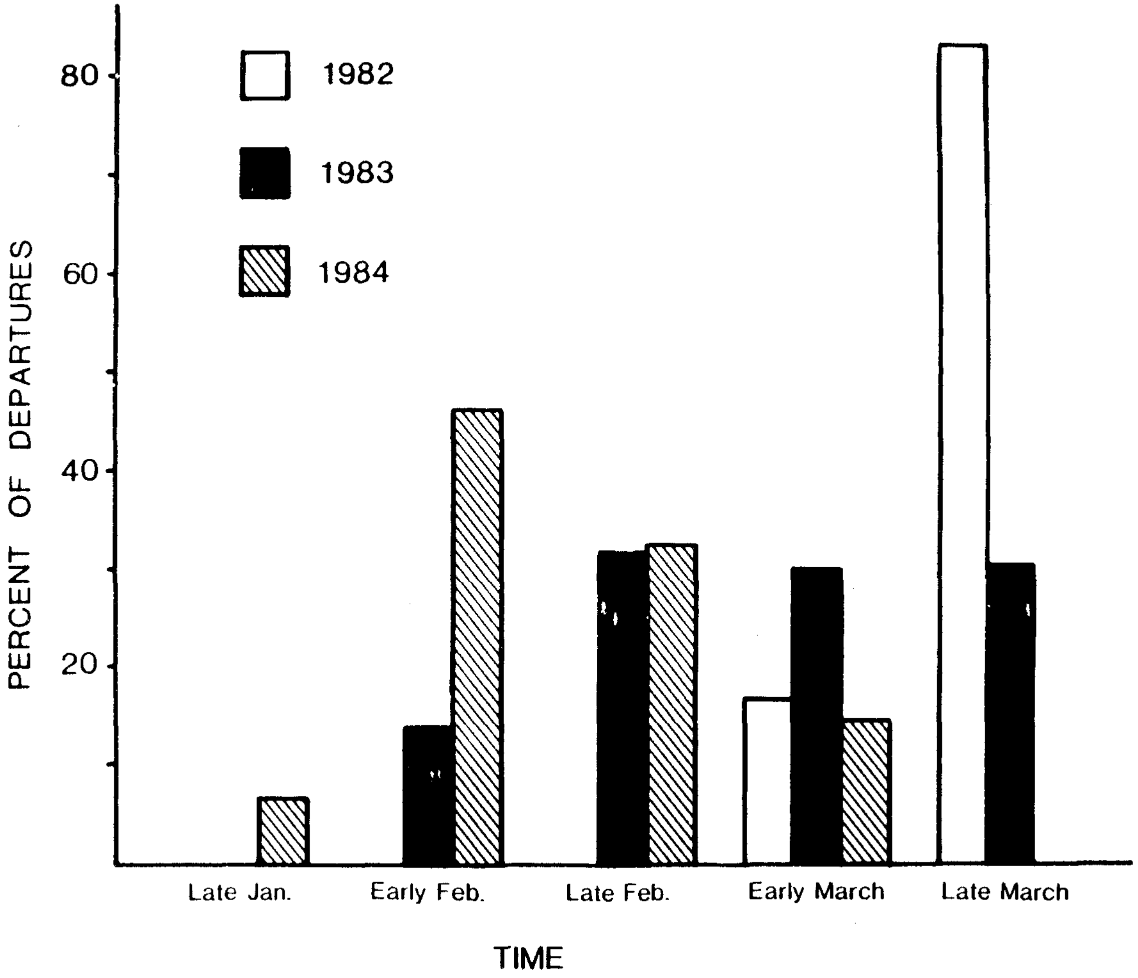

Figure 4. Yearly comparisons of departures of transmitter-equipped Bald Eagles from Rush Valley, UT.

Table 3. Maximum home range sizes of 9 radio-equipped Bald Eagles wintering in Rush Valley, Utah.

Eagle	Age	Sex	Days Tracked	Monitoring Time (hrs)	Roosts Used	Home Range (km^2)
			<u>1982</u>			
AF34	Adult	Female	10	68.0	5	994
AM36	Adult	Male	12	71.6	5	696
AF50	Adult	Female	10	89.1	2	423
			<u>1983</u>			
AF57	Adult	Female	21	172.3	3	1072
AF92	Adult	Female	21	211.2	8	1265
			<u>1984</u>			
AF03	Adult	Female	13	152.1	6	968
AM60	Adult	Male	13	95.5	6	611
AF70	Adult	Female	20	205.1	7	1518
AM75	Adult	Male	10	86.9	4	1093

eagles was an immature, thus precluding comparison of range sizes by age classes.

Home range sizes appeared to be unaffected by monitoring intensity. No significant correlations were found between an eagle's home range size and number of tracking days, hours monitored, or residence duration. These data support the proposal by Marquiss and Newton (1981) that home ranges of some raptors can be accurately calculated after 7 tracking days.

Many of the home ranges of individual birds overlapped. Range boundaries were often far from areas of diurnal perch sites due to the influence of peripheral roosts (Figures 5-12). Diurnal perches of radio-tagged eagles were commonly clustered which suggested regular use of relatively small areas of their home range. Intense observations of a few individuals supported a habitual use of diurnal habitat. One eagle repeated the same sequence of perches and used each for nearly the same length of time on 2 successive days. No defense of diurnal perches or roosting locations was noted, but agonistic encounters were seen at feeding sites.

Diurnal Behavior

<u>Activity</u>. Activity patterns were based on 711.3 hrs of monitoring 17 eagles and were calculated at hourly intervals from 0700 Hrs to 1700 Hrs. Females comprised the bulk of the monitoring time (536.0 hrs) and the dominant age class was adult (617.9 hrs).

The overall activity level for the study period was 22.8%. This value was notably exceeded only between 0600 Hrs and 0700 Hrs

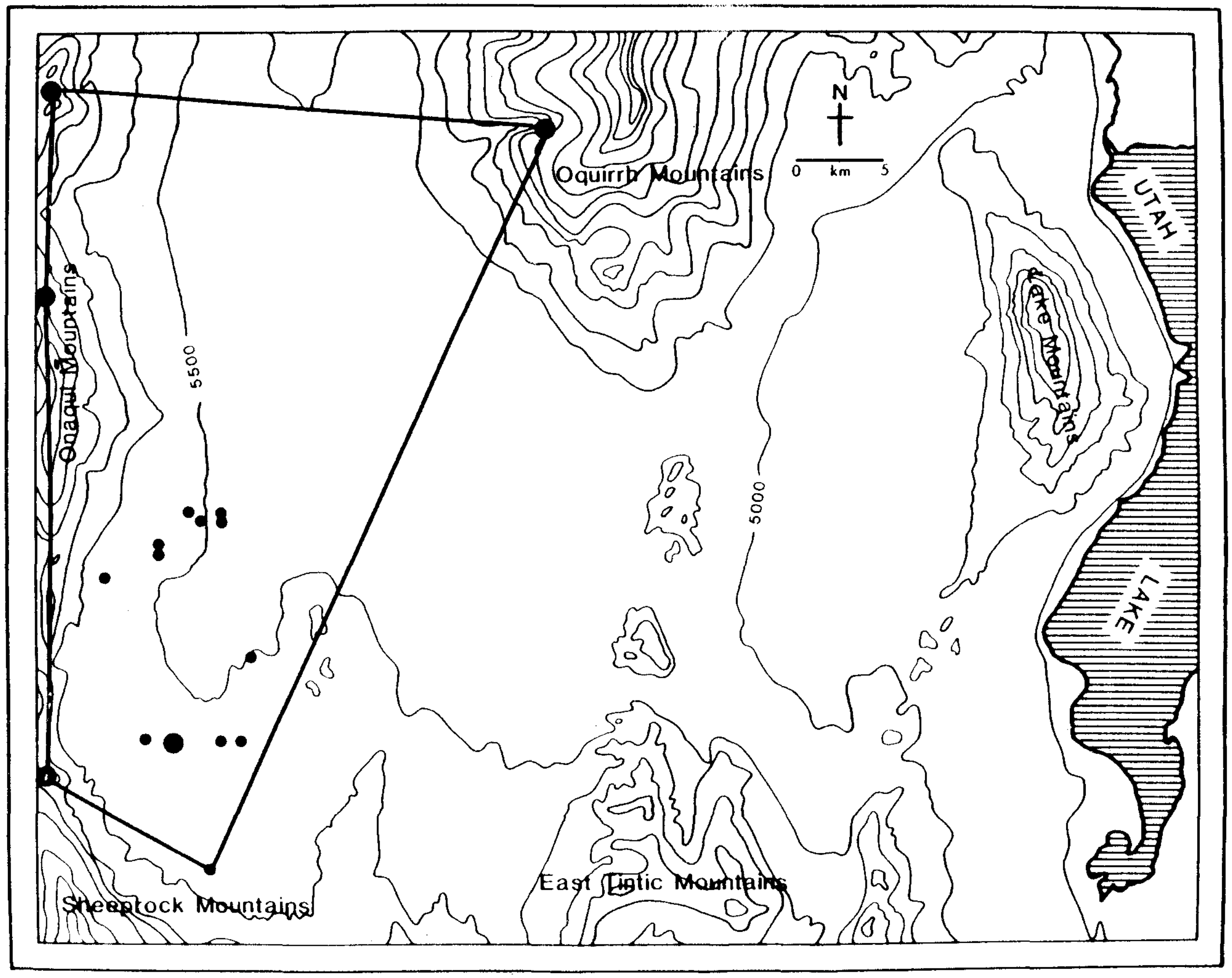

Figure 5. Home range and perch locations (small dots) of AM36 during 1982. Large dots symbolize roosts.

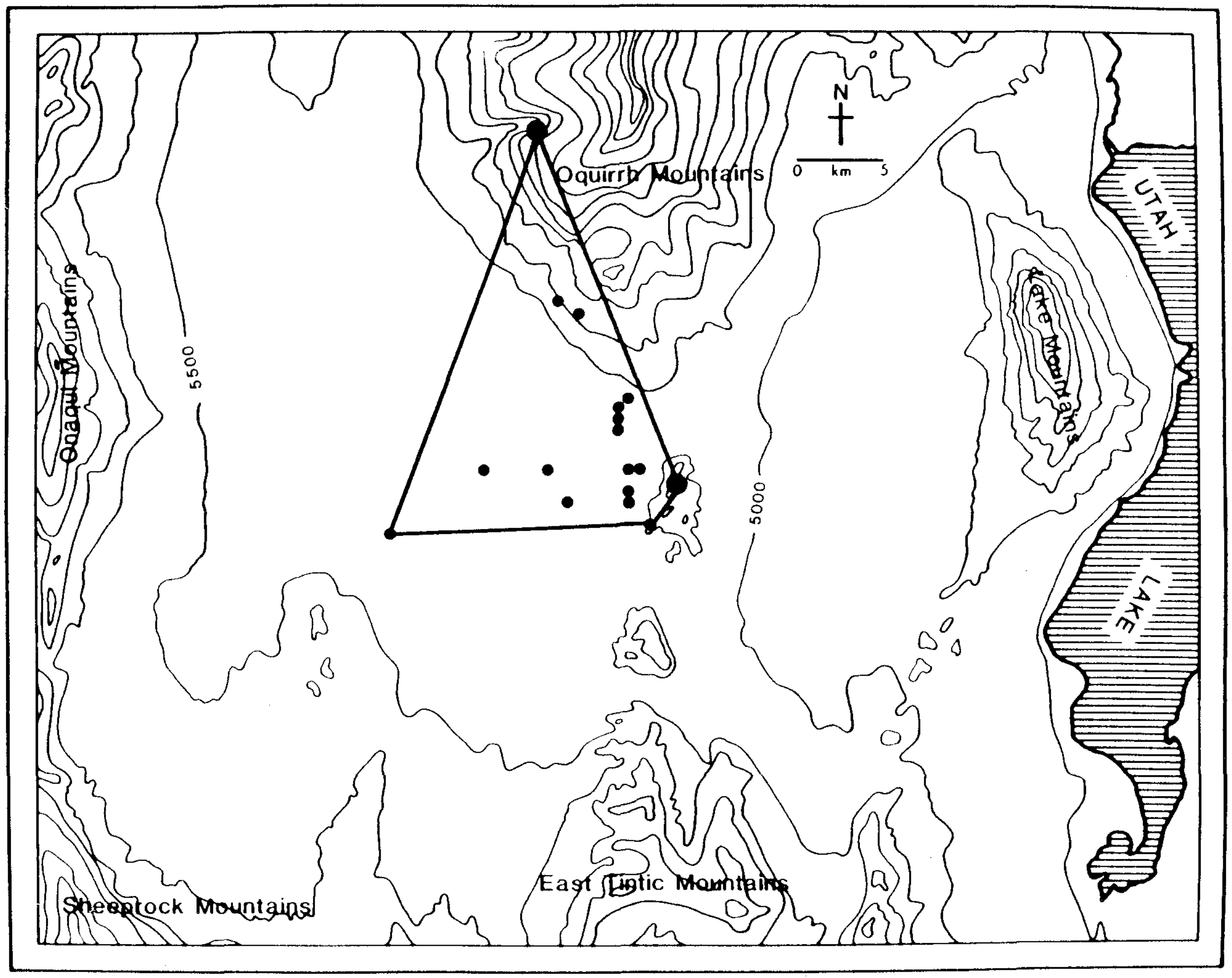

Figure 6. Home range and perch locations (small dots) of AF50 during 1982. Large dots symbolize roosts.

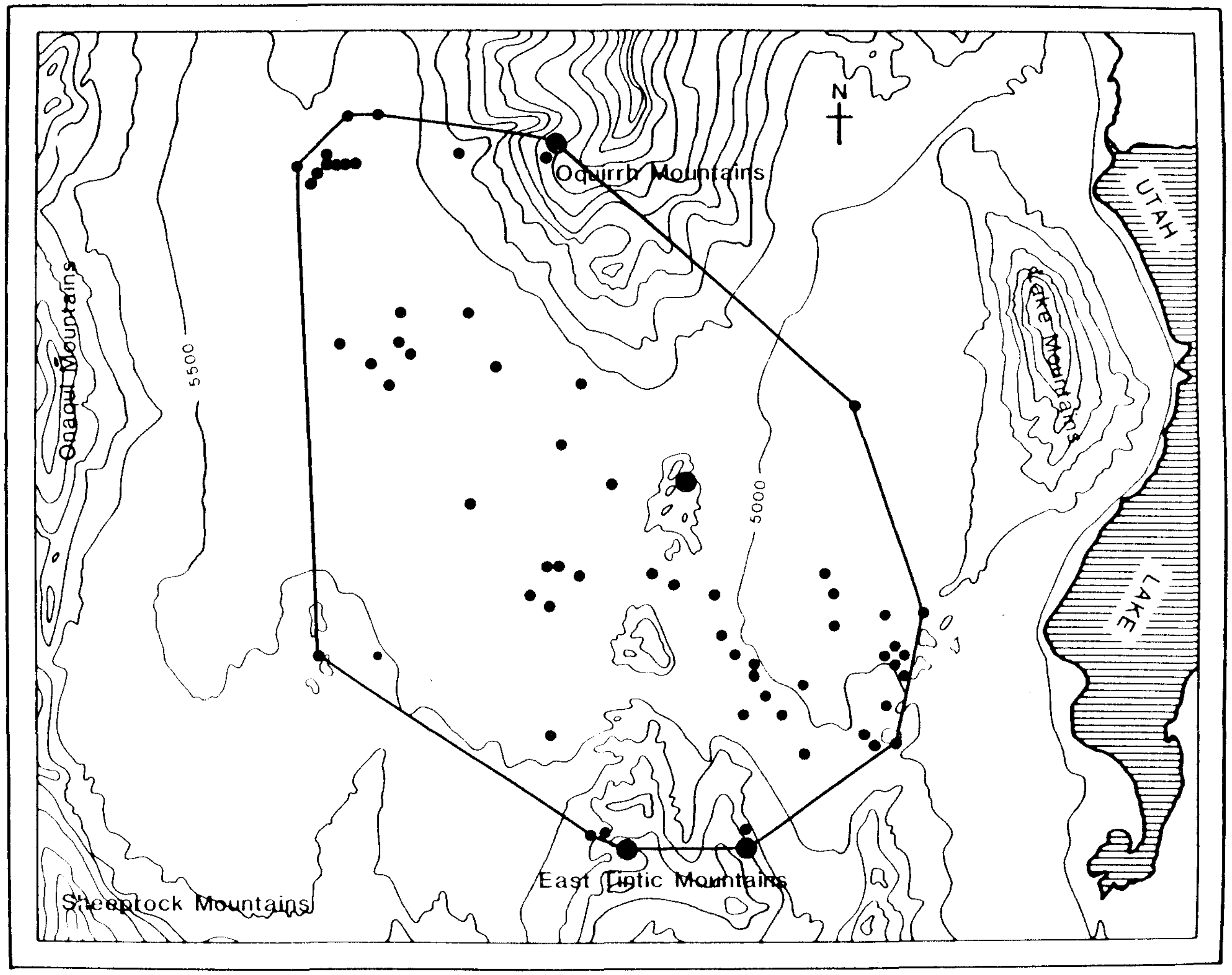

Figure 7. Home range and perch locations (small dots) of IF57 during 1983. Large dots symbolize roosts.

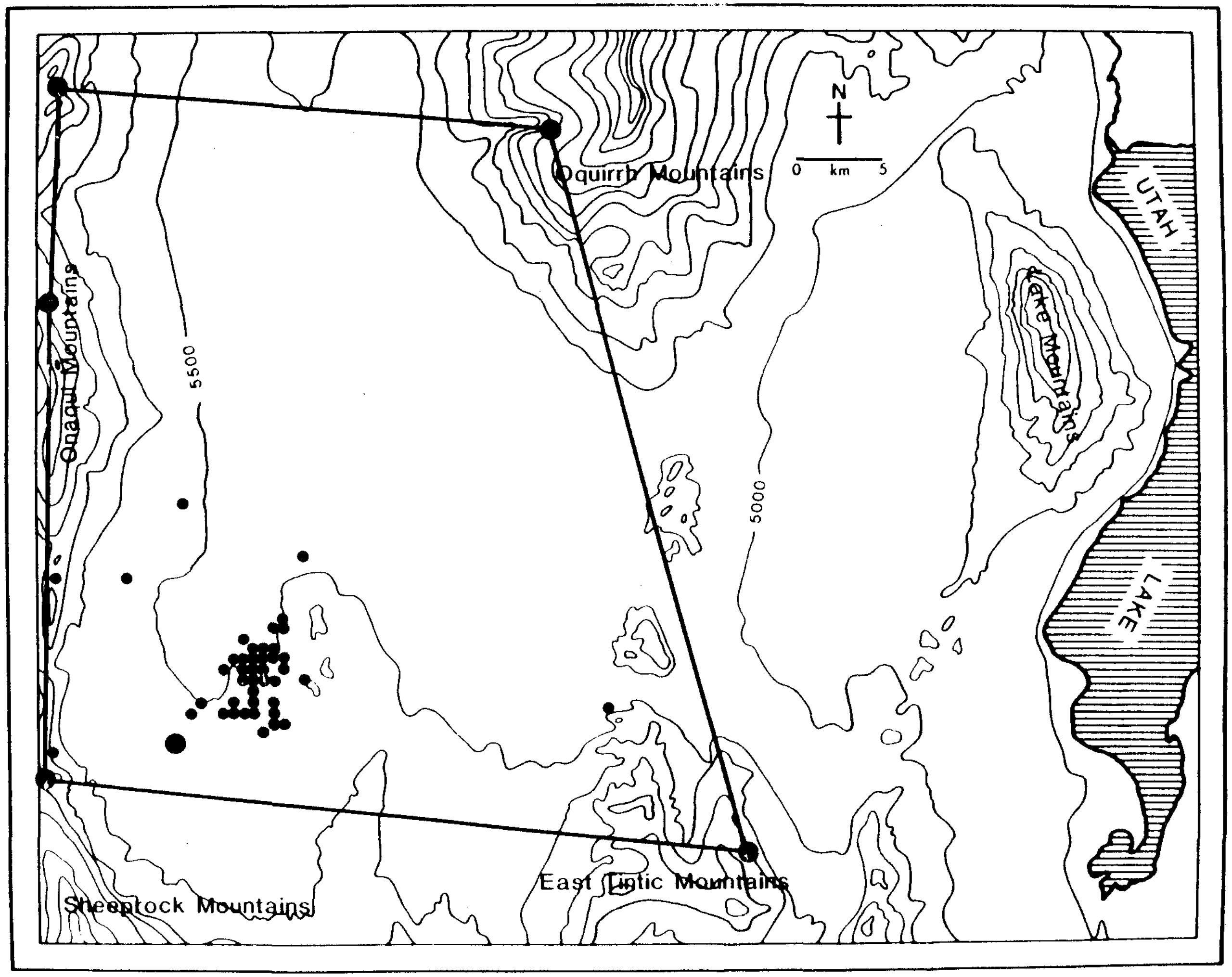

Figure 8. Home range and perch locations (small dots) of AF92 during 1983. Large dots symbolize roosts.

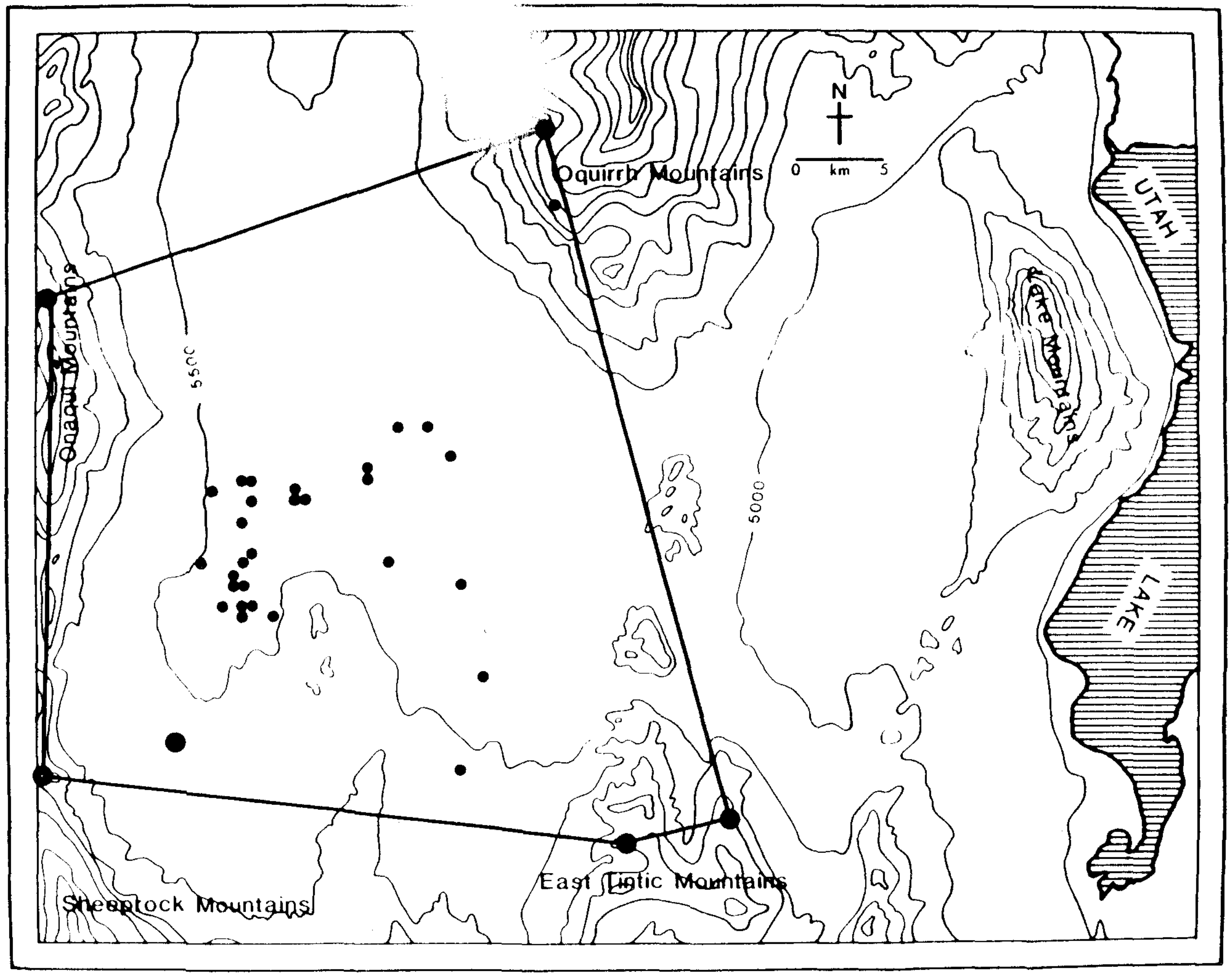

Figure 9. Home range and perch locations (small dots) of AF03 during 1984. Large dots symbolize roosts.

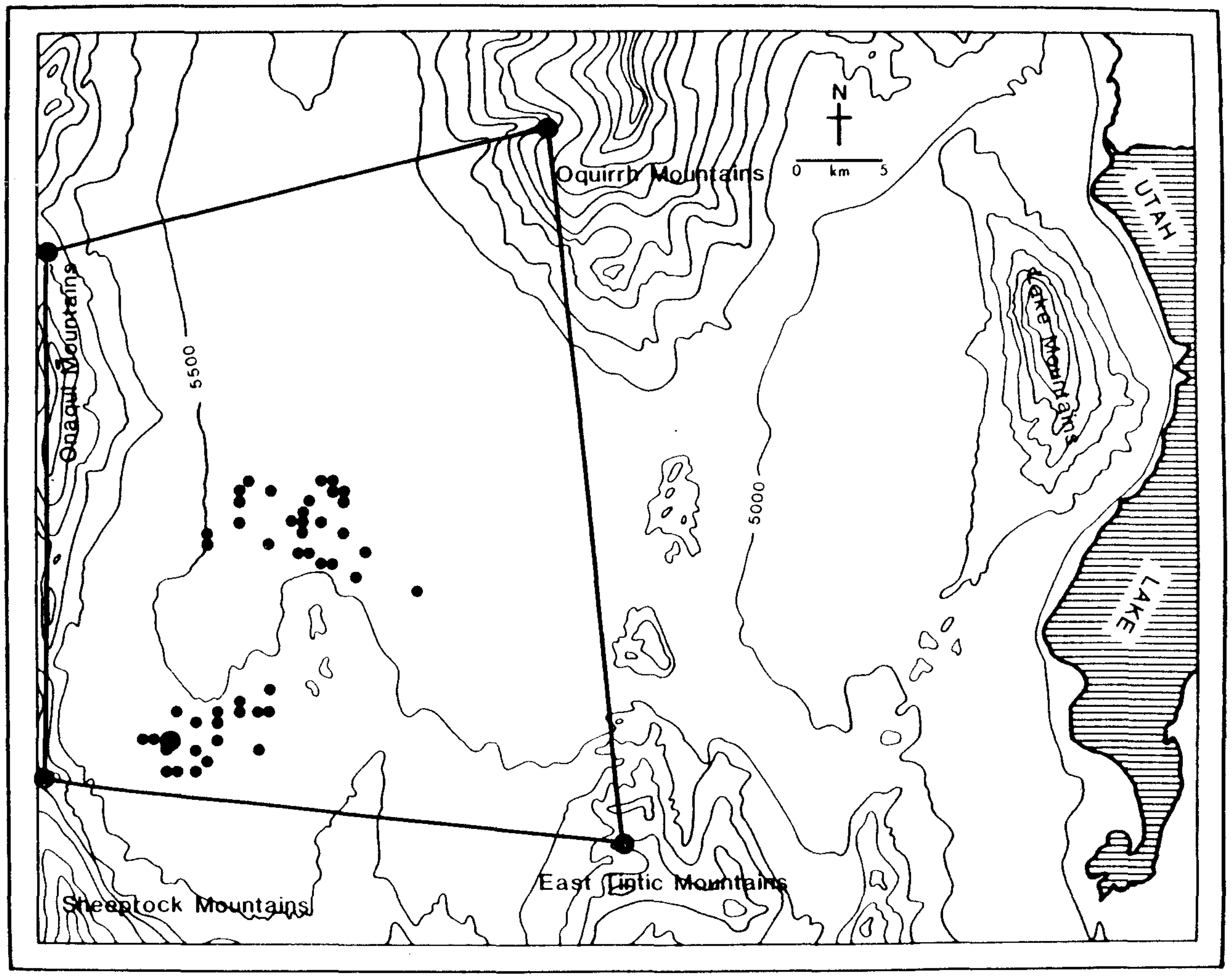

Figure 10. Home range and perch locations (small dots) of AM60 during 1984. Large dots symbolize roosts.

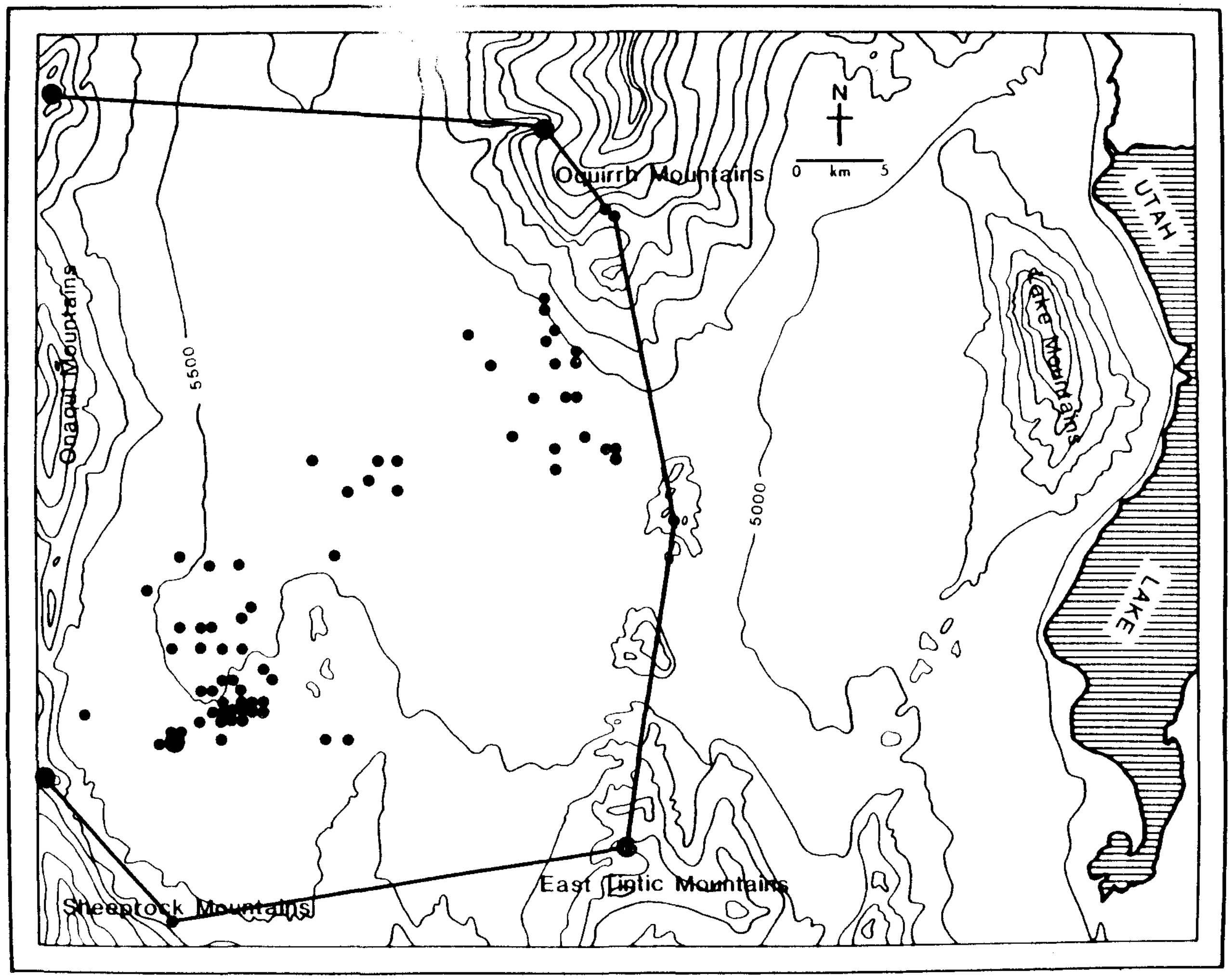

Figure 11. Home range and perch locations (small dots) of AF70 during 1984. Large dots symbolize roosts.

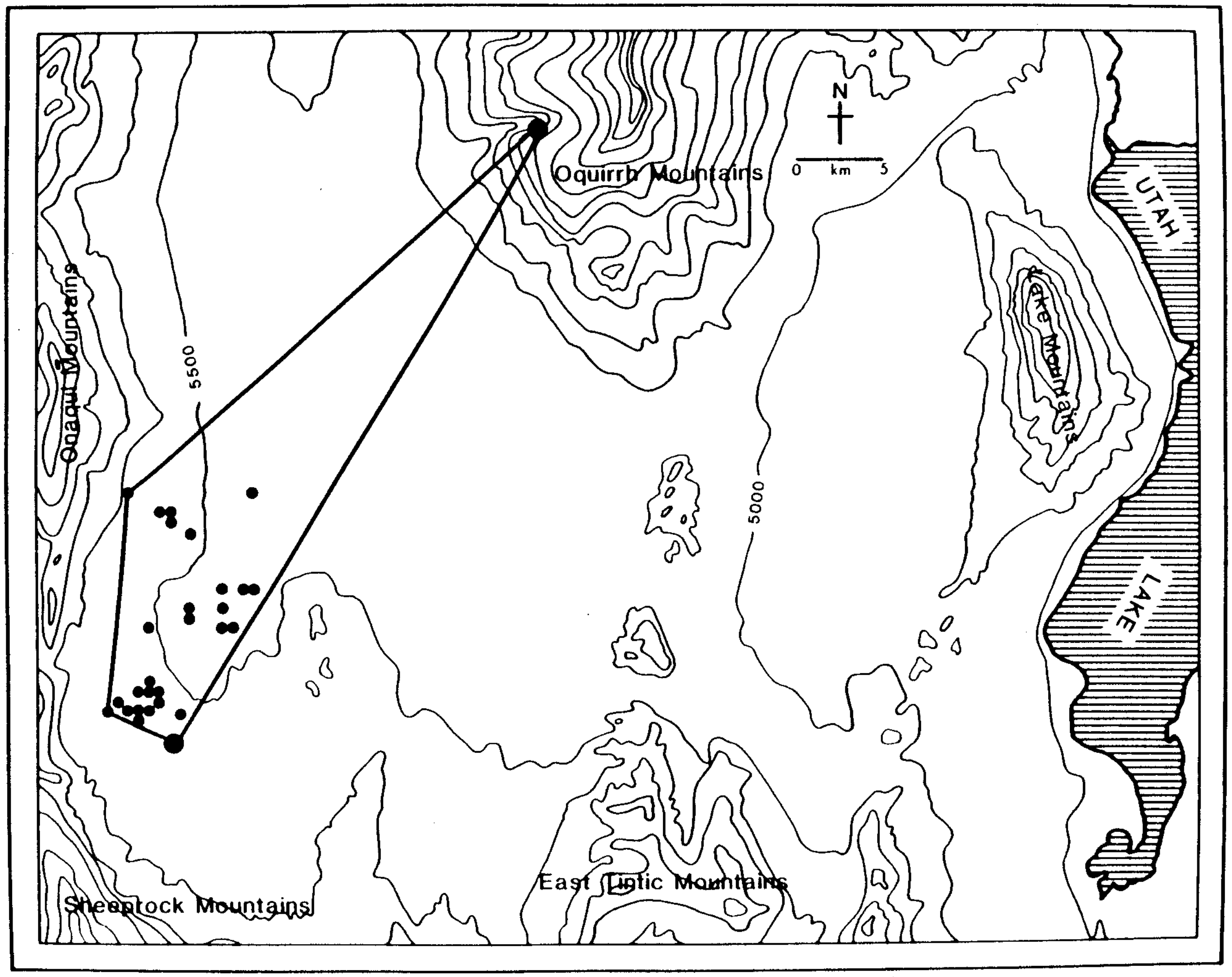

Figure 12. Home range and perch locations (small dots) of AM75 during 1984. Large dots designate roosts.

(Figure 13) and morning roost flights probably accounted for most of this increased activity. No rise in activity levels was associated with evening roost flights, probably because they lacked the synchrony of morning departures.

Activity patterns were not consistent between years (Kruskal Wallis, $p < 0.01$) and declined each year from 1982 to 1984 (Wilcoxon Signed Rank: 1982 vs 1983; $p < 0.01$, and 1983 vs 1984; $p < 0.01$). This pattern was particularly distinctive because yearly declines in activity levels were seen, without exception, across each hour of the day (Figure 14). Female activity levels were also significantly different between years (Kruskal Wallis, $p < 0.001$) and reflected the same pattern as yearly changes. Male monitoring times were low in 1982 so they were pooled with 1983 data and activity levels in these years was once again significantly higher than in 1984 (Wilcoxon Signed Rank $p < 0.05$).

Activity levels varied by sex (Wilcoxon Signed Rank,$p < 0.01$) with males being significantly more active than females (Figure 15). The overall activity level for males was 26.4% compared to 22.6% in females. Immatures were more active than adults (Wilcoxon Signed Rank, $p < 0.01$) and had an overall activity level of 36.3% contrasted to that of 20.8% among adults (Figure 16).

No differences in overall activity levels were seen between months (Kruskal Wallis, NS). No differences were seen in monthly activity levels among females. Males could only be compared between January and February because of insufficient monitoring time during

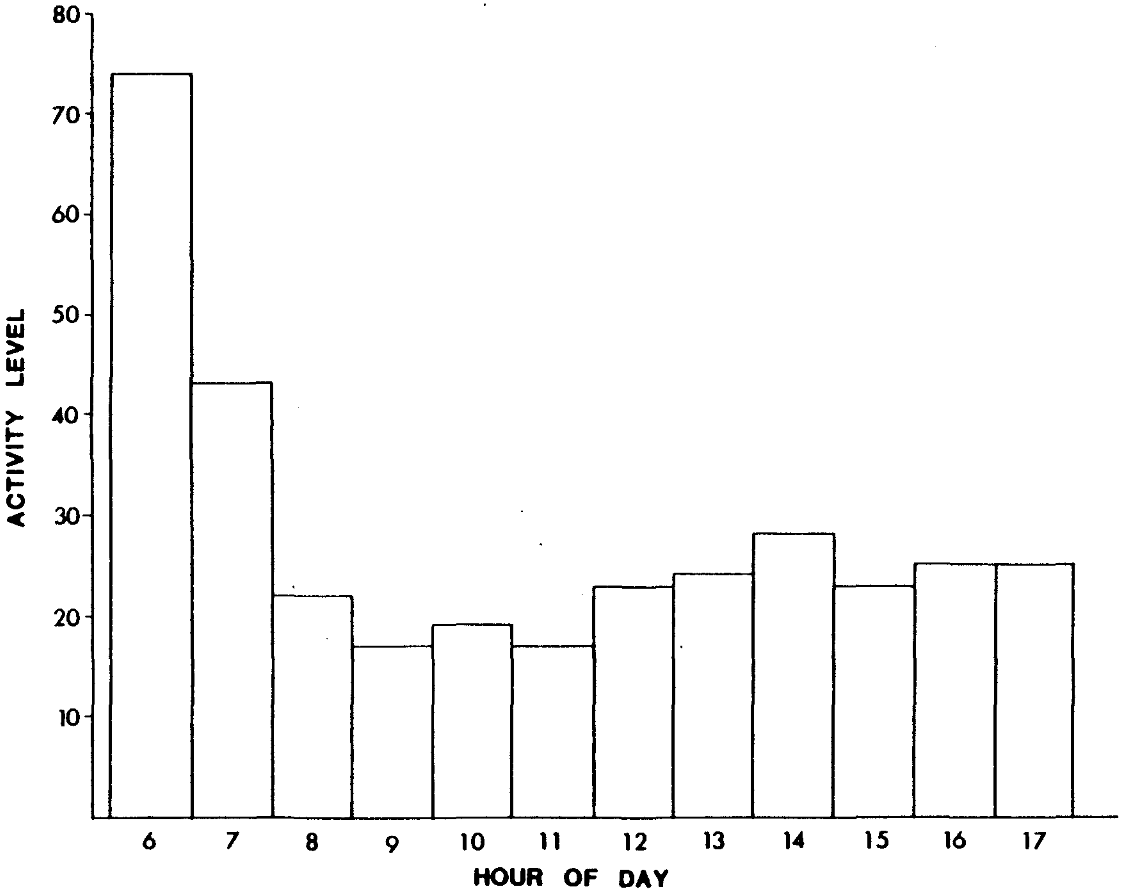

Figure 13. Mean activity levels for 17 transmitter-equipped bald eagles wintering in Rush Valley, UT, 1982-1984.

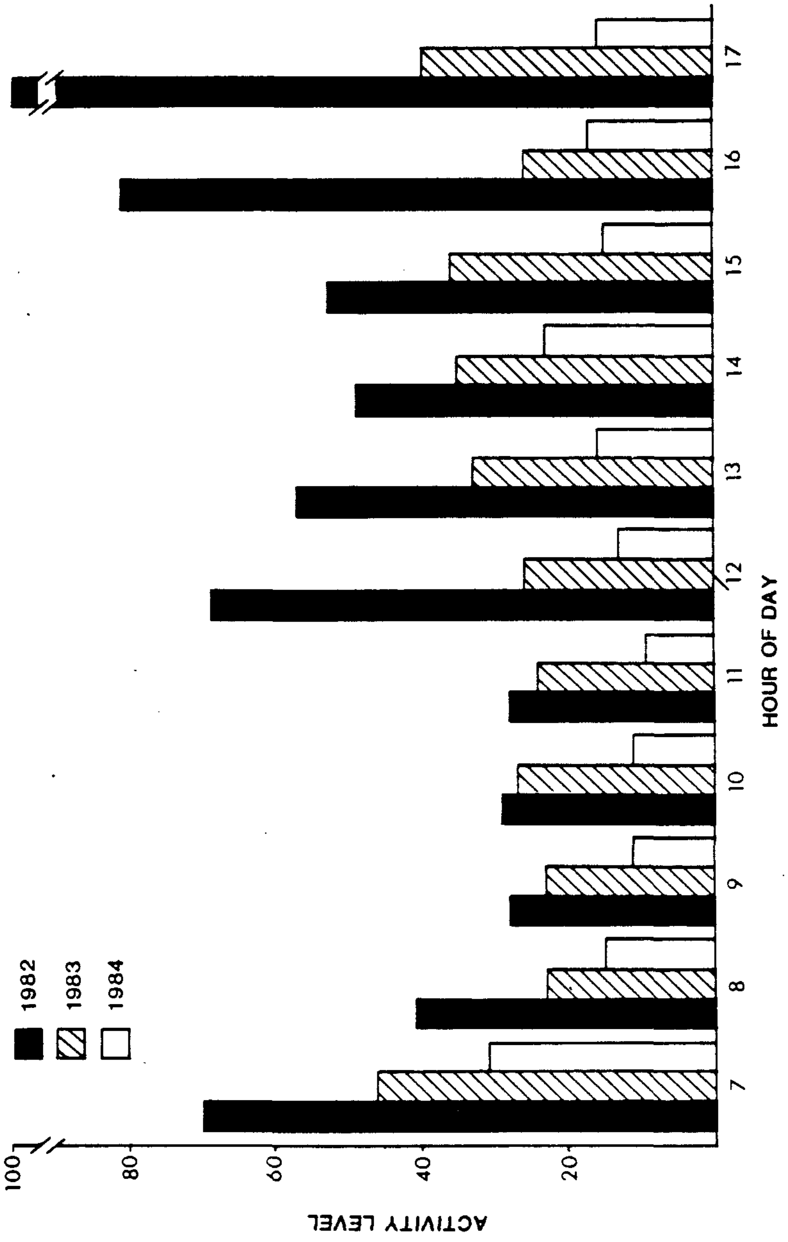

Figure 14. Mean activity level comparisons by year for 17 transmitter-equippped bald eagles wintering in Rush Valley, Utah, 1982-1984.

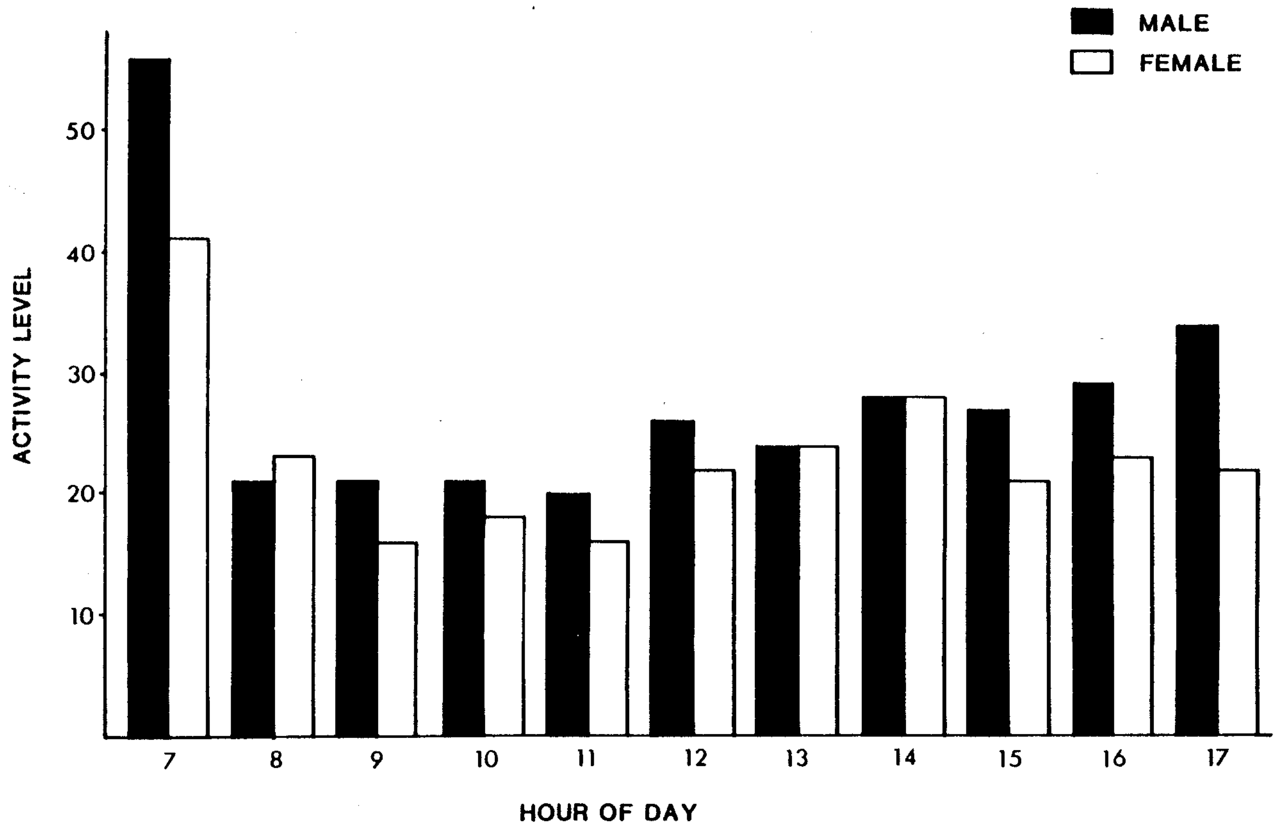

Figure 15. Mean activity level comparisons by sex for 17 transmitter-equipped bald eagles wintering in Rush Valley, UT, 1982-1984.

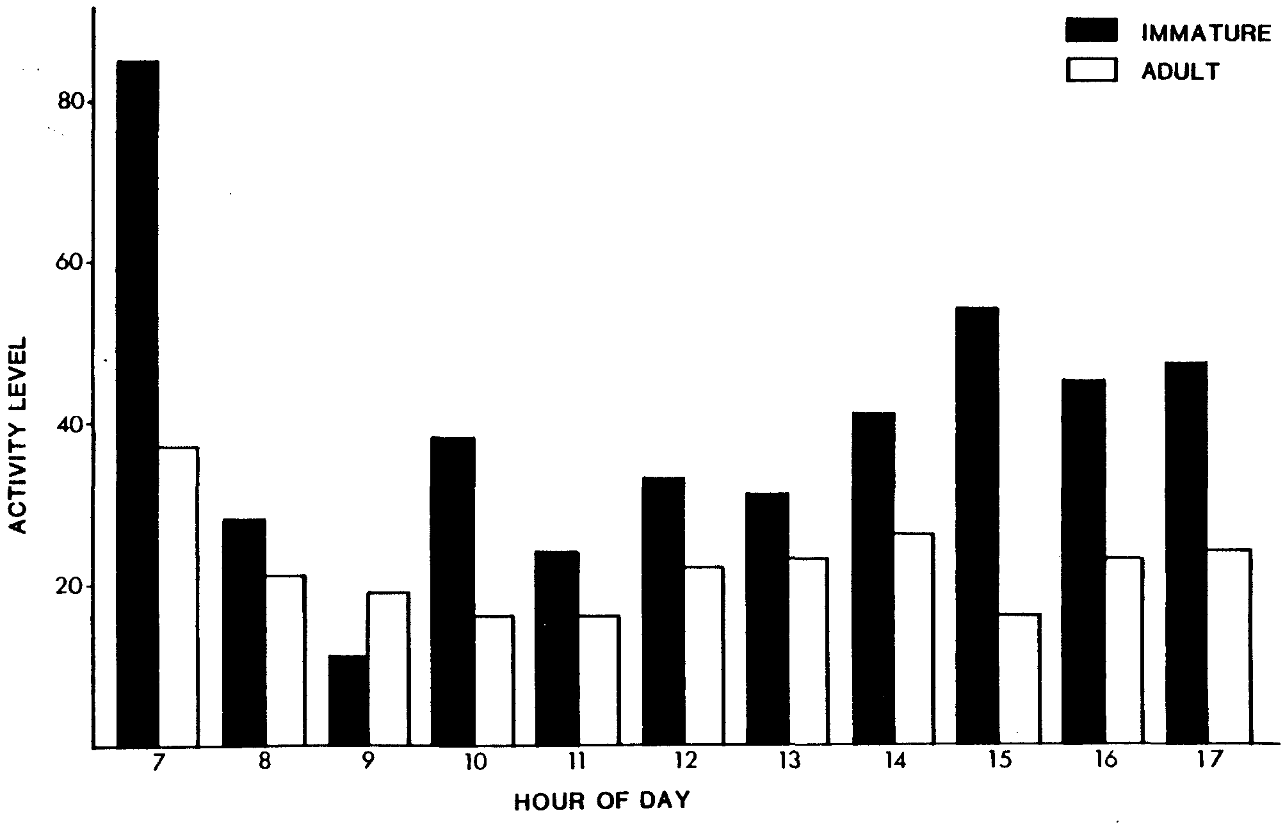

Figure 16. Mean activity level comparisons by age for 17 transmitter-equipped bald eagles wintering in Rush Valley, UT, 1982-1984.

March but no significant differences were seen (Wilcoxon Signed Rank, NS). Immatures lacked sufficient data for monthly comparisons.

Perch Behavior. Diurnal perch sites for 556 marked and 719 unmarked bald eagles were recorded during the study period. Total monitoring time at perch sites used by radio-tagged eagles was 697.1 hrs.

Most eagles perched on the ground and seldom used perches higher than junipers (Figure 17). Birds occasionally perched in isolated clumps of willow (Salix spp.) but these trees were not located near foraging areas. Telephone poles were seldom used but transmission lines often paralleled highways and vehicular disturbances may have prohibited their use.

The distribution of perch locations differed between marked and unmarked eagles (Chi square, $p < 0.0001$) (Figures 18 and 19). Perch sites of marked and unmarked eagles were concentrated in relatively small areas on the valley floor indicating that eagles did not use diurnal habitat relative to its availability (Chi square, $p < 0.0001$).

Initially, there was concern that locations of unmarked individuals would mirror those of marked eagles since both data sets were gathered while tracking radio-tagged individuals. Instead, marked eagles were seen significantly more often near trap sites (Chi square, $p < 0.0001$) and sightings of non-radioed birds were proportionately higher in eastern portions of the valley (Chi square, $p < 0.0001$). Remaining areas had similar frequencies for marked and unmarked birds.

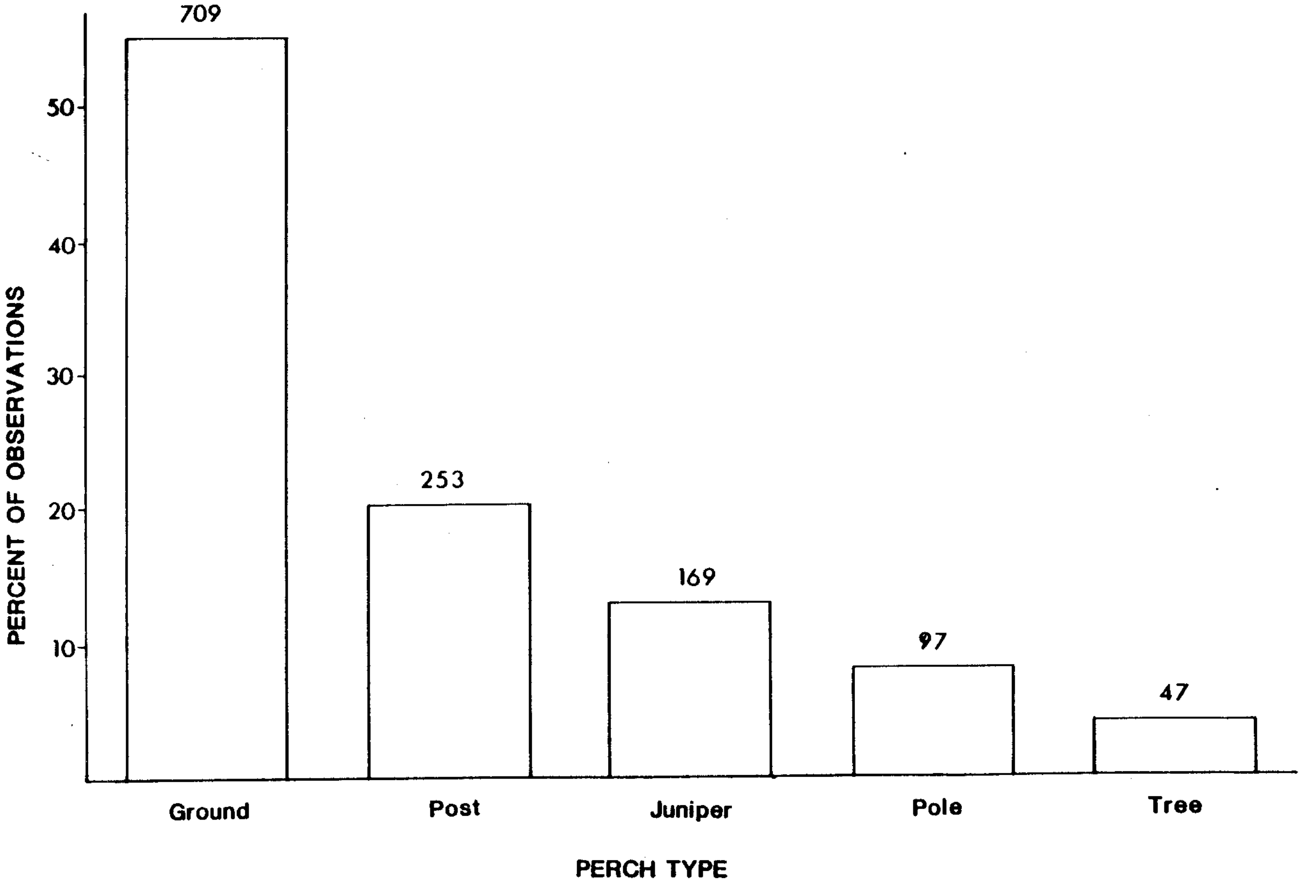

Figure 17. Relative use of perch types by bald eagles wintering in Rush Valley, UT. Number of eagles seen is indicated above each bar.

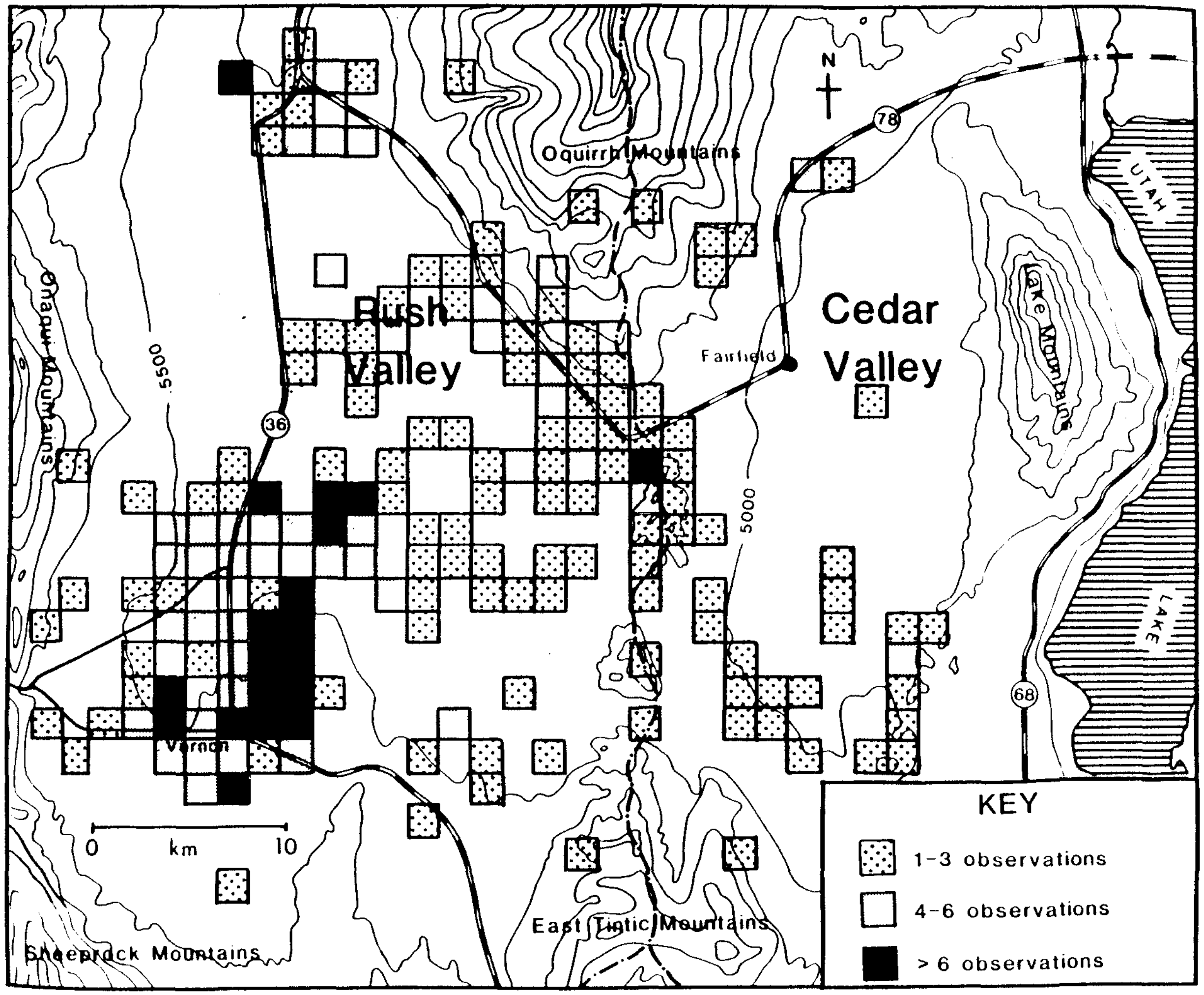

Figure 18. Distribution of perch locations of transmitter-equipped Bald Eagles, 1982-1984.

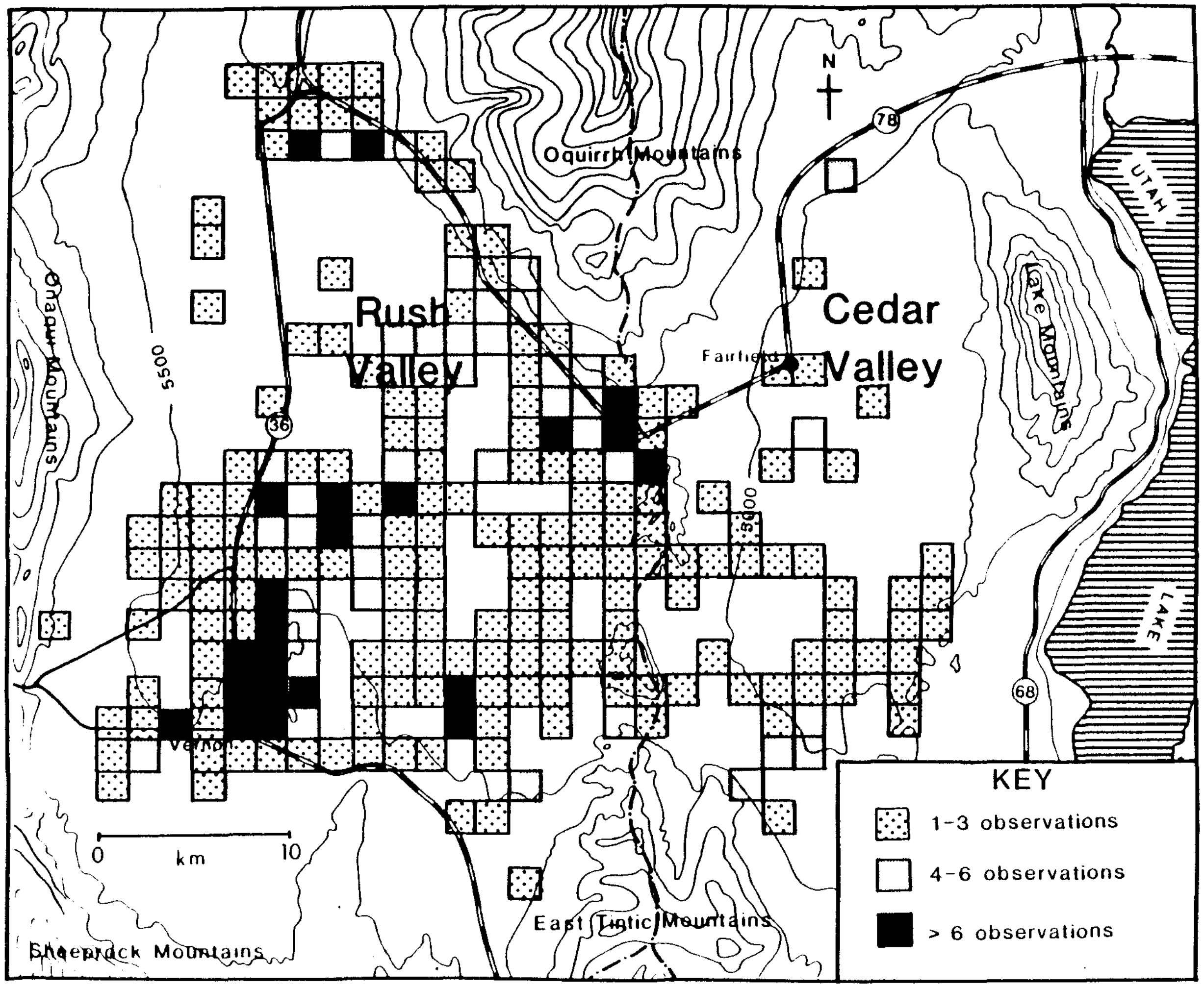

Figure 19. Distribution of perch locations of unmarked bald eagles, 1982-1984.

The difference in distributions of radio-facilitated and casual sightings may be partially explained by observer bias. Perch types of tagged eagles were not equally represented by unmarked birds (Figure 20). Unmarked eagles were seen on telephone poles more often than expected and in junipers less frequently than expected (Chi square, $p < 0.001$). Eagles perched on telephone poles were more easily seen than those in junipers, particularly while the observer was driving. It seems likely, therefore, that eagles perched on the ground, in junipers, or other inconspicuous locations were underrepresented in unmarked bird observations. Perch duration of marked eagles were based on 536.5 hrs of monitoring time. An average perch duration of 52.5 min was calculated from 615 observations. Most (61%) were less than 45 min but a few long perch durations raised the overall average (Figure 21). One-way analysis of variance indicate perch duration did not vary by time of day weekday versus weekends, month or sex.

Perch duration, however, was affected by year and perch type (ANOVA, $p < 0.05$, and $p < 0.001$, respectively). An average perch duration of 54.3 min ($N = 39$) in 1984 was significantly longer than that of 34.4 min in 1982 (Scheffe test, $p < 0.05$).

Perch type also affected perch duration (ANOVA, $p < 0.01$) with perches closest to the ground having the shortest durations. Less time was spent by eagles perched on the ground compared to those on fenceposts or in deciduous trees (Scheffe test, $p < 0.05$).

Flight Behavior. Speeds and minimum distances of 348 diurnal flights were recorded on 16 radio-tagged individuals. An average overall

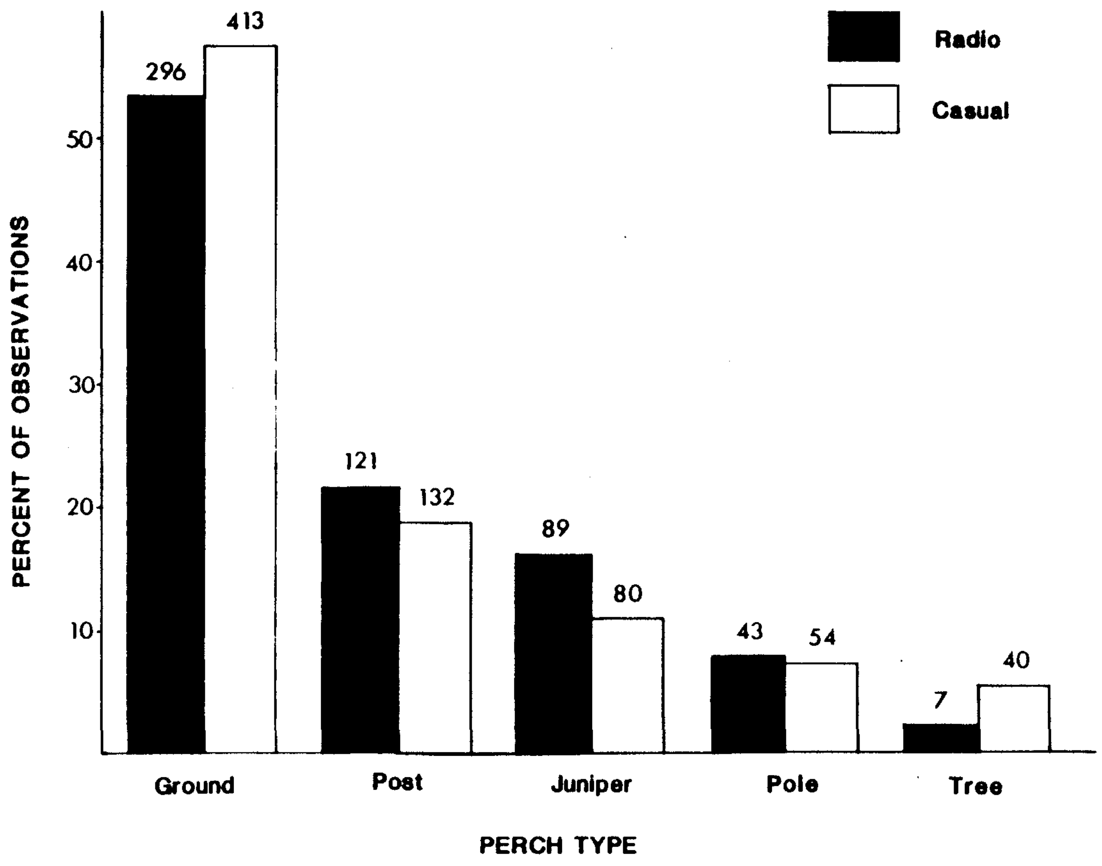

Figure 20. Comparison of perch types use by marked and unmarked bald eagles, 1982-1984. Number of eagles seen is indicated above each bar.

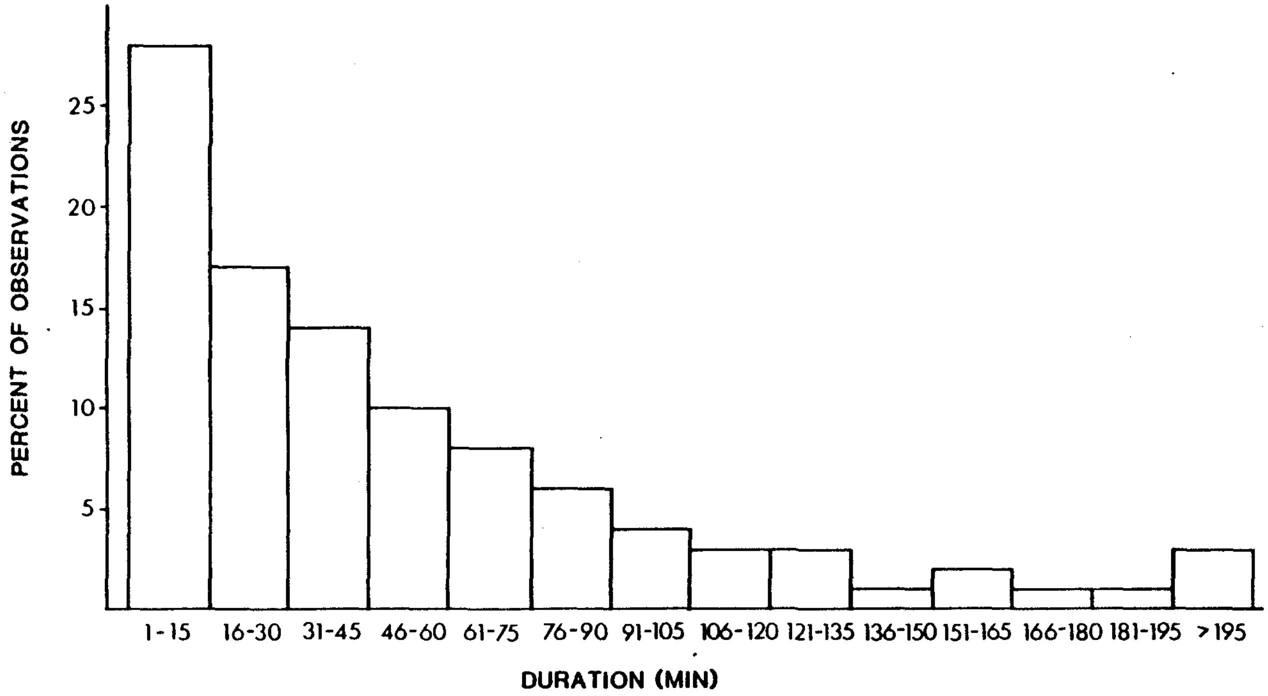

Figure 21. Distribution of perch durations (N = 615) of 22 transmitter-equipped bald eagles wintering in Rush Valley, UT.

flight distance of 2.9 ± 4.0 km was calculated, with most flights (71%) under 3 km (Figure 22). Average flight speed for all eagles was 41.8 ± 33.1 km/hr. Flight distance and speed were relatively stable during the study period. Analysis of variance indicated no significant differences in these parameters either between years, months, times of day, sex, or age (Table 4).

Flight durations were based on 160.5 hrs of monitoring involving 735 observation on 22 marked eagles. Mean duration of all flights was 13.1 ± 24.7 min. Most flights (60%) were under 5 min long and these short, direct flights were routinely used between habitual perches (Figure 23). As flight duration increased, soaring and flapping were intermittently used. Most flights over 15 min involved some soaring and it became the dominant locomotor mode in flights over 30 min. Soaring was common on warm, clear days when eagles took advantage of rising thermals. Direct flights took place under any weather conditions and were most numerous when eagles were foraging. Significant differences in flight duration were found between years (ANOVA, $p < 0.001$). Comparisons of yearly means (Scheffe test, $p < 0.05$) indicated a continual decline in flight duration from 1982 to 1984 (Table 4). Both male and female flights became shorter between 1982 to 1984 (ANOVA, $p < 0.01$ and $p < 0.001$, respectively). Mean durations of male flights were shorter in 1984 than 1982 or 1983 but female flights became significantly shorter each year (Scheffe test = 0.05). Overall, immature flights ($\bar{x}$ =18.8 ± 31.9 min) lasted longer than those of adults (12.2 ± 23.2) (t test, $p < 0.02$) but monitoring time on immatures was insufficient for yearly comparisons.

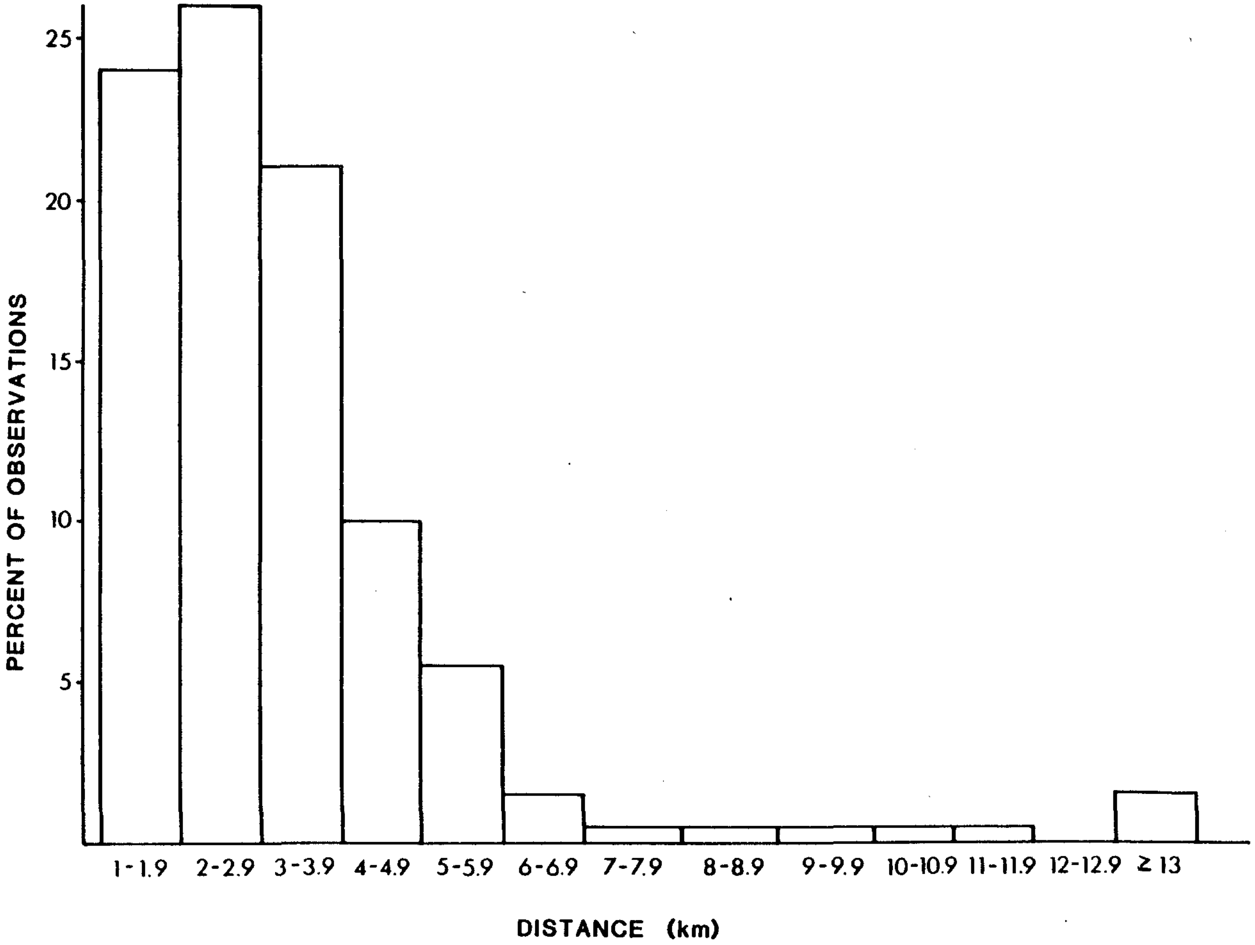

Figure 22. Distribution of flight distances (N = 348) of 22 transmitter-equipped bald eagles wintering in Rush Valley, UT.

Table 4. Yearly comparison of diurnal flight characteristics among radio-equipped Bald Eagles in Rush Valley, Utah. Probabilities (p) for differences between years are based on One-way Analysis of Variance.

	Year			
	1982	1983	1984	p
Distance (km)	2.6 5.8 (N=55)	3.2 3.8 (N=91)	2.7 3.2 (N=202)	NS
Speed (km/hr)	38.4 31.8 (N=55)	37.0 31.8 (N=91)	44.8 33.4 (N=202)	NS
Duration (min)	31.3 31.7* (N=79)	16.9 29.4* (N=201)	8.3 18.5* (N=456)	$p<0.001$

* significantly different (Scheffe test $p < 0.05$) than other years

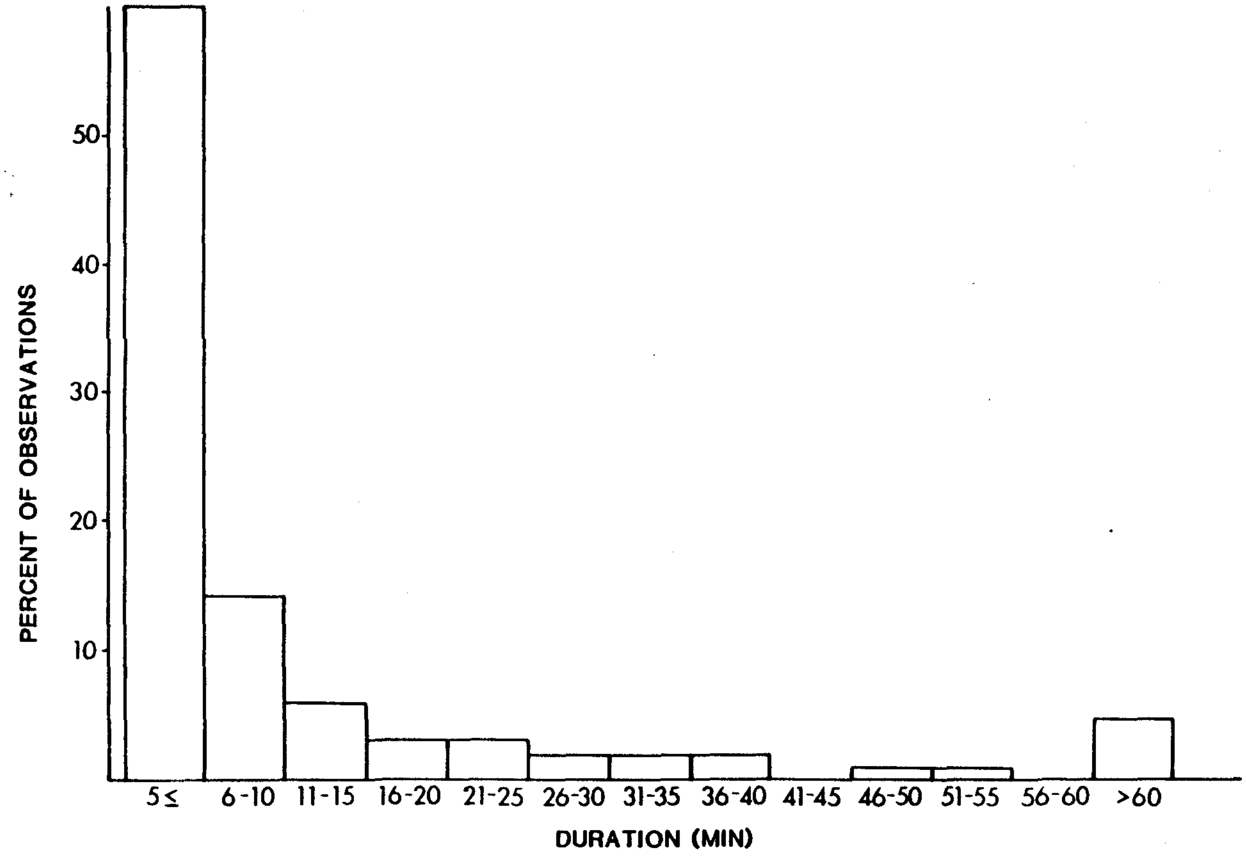

Figure 23. Distribution of flight durations (N = 735) of 22 transmitter-equipped bald eagles wintering in Rush Valley, UT.

No differences in flight durations were found between months, times of day or sex. Eagles also reduced relative flying time from 1982 (51%) to 1984 (15%).

Habitat Use. Diurnal perches of marked eagles monitored over 45 hrs were typically concentrated in two small areas of their home range. Comparison of topographic features between areas of eagle use and random sites indicated eagles selected relatively flat areas for perching (Chi square, $p < 0.001$). Most eagles perched on the ground and visibility of the surrounding terrain was limited. The selection of flat areas for perching probably minimized the chance of an eagle being approached closely from any direction without detection. No ground perches were in completely flat areas and slope appeared to influence eagle use (Chi square, $p < 0.01$). Eagles used areas with south to southeast slopes more than expected and avoided those with northwest to northeast slopes. No significant differences were found in the number of elevated areas between random and eagle use areas.

Areas of eagle use did not appear to be influenced by road type (Chi square, NS) or number (t test, NS). Most road types inventoried (63%, $N = 140$), however, had dirt substrates and many were not accessible through all or part of the wintering period, depending on weather conditions. Eagles in habitually used areas were therefore at least partially insulated from vehicular disturbance. Nearly all human activity in eagle use areas involved hunting, and these intrusions were typically on foot. Human disturbance of eagles was a rare occurrence and was involved in less than 0.5% ($N = 652$) of the perch observations collected.

Importance of Diurnal Habitat

Importance values were based on 1441 perch locations and 527.4 hr of monitoring time. Townships were divided into quarters and values were calculated on 56 that were at least partially below 1750 m (Table 5). Each quarter was then classified as an area of low, medium, or high eagle use.

Since perch distributions of radioed and non-radioed eagles differed, the sum of all observations in each quarter was believed to be the best value to compute relative sightings. Relative durations remained based on the behavior of marked birds which probably biased the final values calculated. Sites of eagle use, therefore, should be used in conjunction with all information available on bald eagles wintering in Rush Valley.

Low Use Areas. Twenty-two quarters had importance values below 0.5 and were designated low eagle use areas. Few eagles were seen (x = 2.5 eagles/quarter) in most of these quarters and no eagles were recorded in half of them; marked birds also spent little time there (x = 8 min/quarter).

Of the 27 quarters which bordered the valley floor, 16 fell into this category (Figure 24). Eagles were never seen feeding in low use areas and it was believed that these quarters were largely used for non-foraging activities. Jackrabbit habitat within these sites was limited to small isolated patches, and 2 quarters (R5T6 NW and SW) were covered largely by winterfat and mixed grasses which can support only moderate rabbit numbers (USDI 1979, p. 37). These quarters were partially included within the Tooele Army Depot, and human activity

Table 5. Importance values for diurnal habitat below 1750 m in Rush Valley, Utah.

Location		Sightings			Monitoring	Importance
Twnsp	Qtr	Marked	Unmarked	Total	Time (hrs)	Values
3/6	NW	4	1	5	2.5	0.4
	SW	9	16	25	5.8	1.4
	SE	-	2	2	0.0	0.1
3/7	NW	20	60	80	12.5	3.9
	SW	6	22	28	3.2	1.3
3/8	NW	2	5	7	0.7	0.3
	SW	2	8	10	3.8	0.7
4/5	NW	1	-	1	0.6	0.1
	SW	1	16	17	0.5	0.6
4/6	NE	4	9	13	3.2	0.8
	NW	2	12	14	1.7	0.6
	SW	6	12	18	6.3	1.2
	SE	16	53	69	11.5	3.5
4/7	NE	8	37	45	10.2	2.5
	NW	4	16	20	8.3	1.5
	SW	6	21	27	5.6	1.5
	SE	2	11	13	5.0	1.0
4/8	NE	3	15	18	2.0	0.8
	NW	3	14	17	3.3	0.9
	SW	3	27	30	2.7	1.3
	SE	2	28	30	4.9	1.5
4/9	NE	-	5	5	0.0	0.2
5/5	NE	6	21	27	5.3	1.4
	NW	8	6	14	3.2	0.8
	SW	2	3	5	0.8	0.3
	SE	21	60	81	15.3	4.2
5/6	NE	3	8	11	3.3	0.7
	NW	-	2	2	0.0	0.1
	SW	1	1	2	0.7	0.1
	SE	5	8	13	4.0	0.8
5/7	NE	1	11	12	0.7	0.5
	NW	1	7	8	0.1	0.3
	SW	42	64	106	45.1	8.1
	SE	45	116	161	52.5	10.7
5/8	NE	16	33	49	16.6	3.3
	NW	57	95	152	47.5	9.9
	SW	83	91	174	84.2	14.4
	SE	32	48	70	29.7	5.4
5/9	NE	7	3	10	0.0	0.3
	NW	9	33	42	17.2	3.2
6/7	SW	0	2	2	0.0	0.1
	SE	8	7	15	8.6	1.4
6/8	NE	6	6	12	6.2	1.0
	NW	2	4	6	5.1	0.7
	SW	5	0	5	4.9	0.7
	SE	29	34	63	38.7	6.1

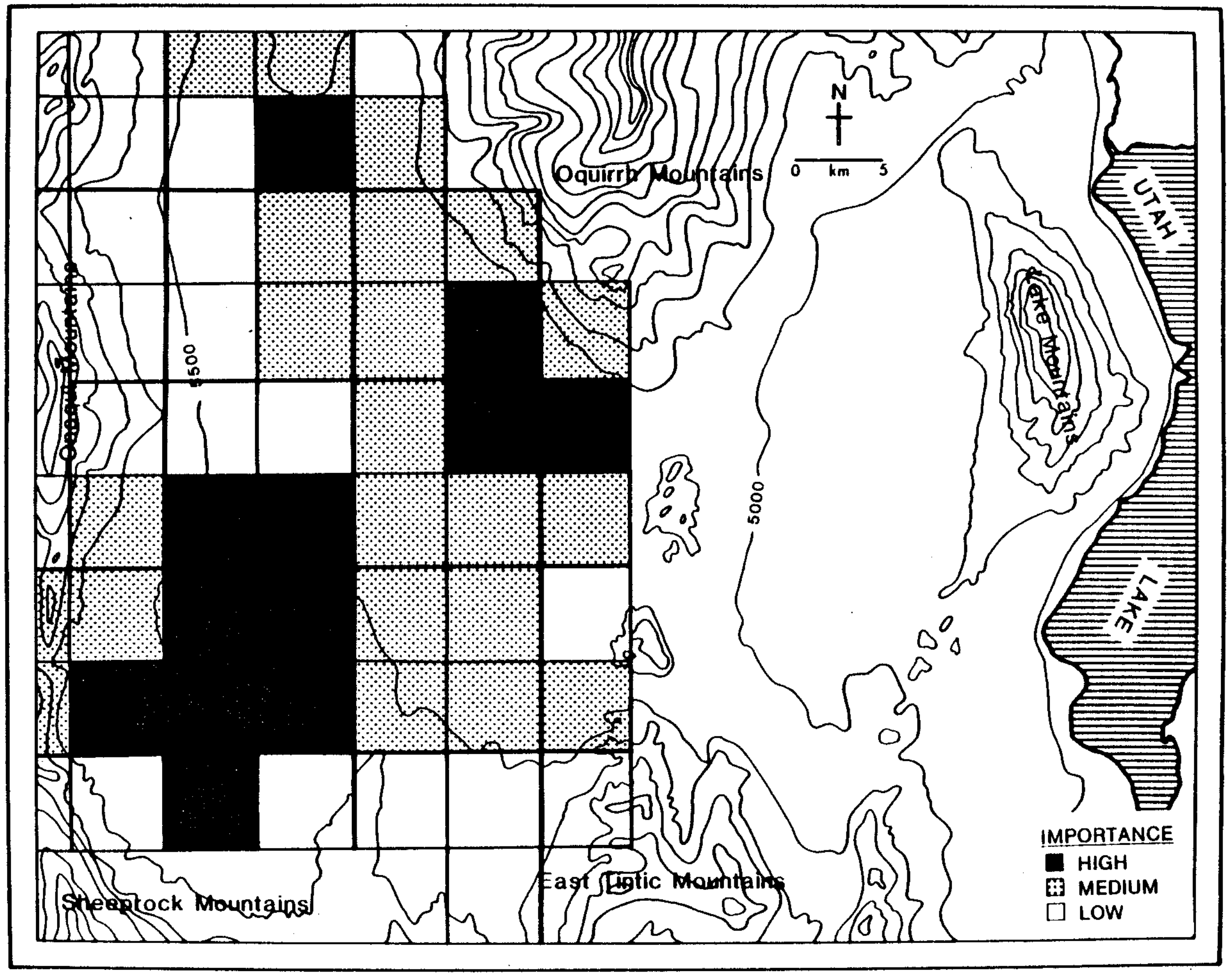

Figure 24. Relative importance to bald eagles of diurnal habitat below 1750 m in Rush Valley, UT.

there may have also further discouraged eagle use. The remaining 14 quarters were subject to flooding, cattle grazing, or cultivation and these conditions undoubtedly limited jackrabbit numbers. Most perch sites were also relatively inaccessible by vehicle and the few eagles which used them may have been attracted because of their isolation from human disturbance.

<u>Medium Use Areas</u>. Medium use areas had importance values from 0.5 to 2.0; 22 quarters, mostly in the eastern portion of the valley, fell into this category (Figure 24). Eagle sightings averaged 17.0/quarter and mean monitoring time per quarter was 264 min.

Medium use was the only category to have proportionately fewer sightings of radio-tagged eagles (Chi Square $p < 0.001$). Although a number of biases associated with sampling (visibility, terrain, access, etc.) could explain these differences, I believe it was due principally to trapping location. As previously discussed, eagles were only trapped in the southwestern portion of the valley and most medium use areas were in the valley's eastern portion. The distance of these sites from habitual foraging areas used by marked birds may have led to underestimating their importance. It is also likely that wintering eagles in different parts of the valley habitually used different feeding areas. The importance of some medium use areas may therefore be underestimated, and additional data should be collected before management practices in these areas are changed, particularly in those with relatively high importance values (Table 5).

Food appeared to be periodically abundant in medium use areas. Shadscale, greasewood, and sagebrush were common and these provided good forage and cover for jackrabbits. Jackrabbit hunting also occurred throughout most of the winter in habitat adjacent to open roads. Radio-tagged eagles were seen feeding on carrion in medium use quarters 7 times (4 jackrabbit, 1 sheep, 2 unknowns).

<u>High Use Areas</u>. Twelve quarters had importance values over 2 and were designated high use areas. The highest average number of sightings ($\bar{x}$ = 91/quarter) and the longest mean monitoring time ($\bar{x}$ = 40.06 hrs/quarter) were recorded here.

High use areas were located in 2 general regions on the valley floor. Eight were near Vernon and 4 were situated in the northeastern portion of the valley (Figure 24).

The 8 quarters near Vernon included: 1) the 2 southern quarters in R5T7, 2) 4 quarters in R5T8, 3) the northwest quarter of R5T9, and 4) the southeast quarter of R6T8. Over half of all the eagles seen during the study and nearly three-quarters of the perch time of radioed birds were recorded in high use areas.

The habitual use by marked eagles of diurnal sites near Vernon undoubtedly increased their importance values. Areas near Vernon were used on a daily basis by a substantial number of wintering eagles. Fidelity to these diurnal sites by marked birds, however, may have led to the underestimation of importance values of quarters outside of the Vernon area. These quarters would most likely be medium use areas (particularly in the eastern portion of the valley) because of the low number of marked eagles sighted there.

Nearly all eagles seen and monitored in R5T7 were in its 2 southern quarters (93%, N = 237, and 99%, N = 19 hrs, respectively).

Sightings were usually east of Faust within 2 km of the Pony Express Road. Eagles were often seen perched on knolls and small hills scattered throughout the area. A roost, consisting of a single juniper on top of a small hill, was located in section 36 during 1984. Over 20 eagles were seen here on one occasion and it was used daily for at least 2 months. Marked eagles were tracked from this roost to carcasses in R5T7 and its use probably allowed eagles to roost close to food sources. Eagles were seen feeding in this area on 16 occasions. Most carcasses (56%) were unidentified but eagles were seen feeding on 5 sheep and 2 jackrabbits. Most sheep deaths were presumably attributable to injuries incurred during transport between grazing areas. These carcasses provided a reliable food source for several days to weeks, depending on the number of eagles feeding on them.

R5T8 was the only township where all quarters received high eagle use. Most (83%, N = 445) sightings in this range were west of the Vernon Hills and east of State Highway 36; perch time was also concentrated in this area (74%, N = 278 hrs). Ephemeral streams dissected the lower western slopes of the Vernon Hills into a series of isolated hills and a broad, flat streambed ran parallel to their bases. Eagles were often seen perched on higher elevations east of the streambed and regularly flew along the drainage. Nearly one third of all carcass feeding observations (32%, N = 78) were in R5T8, which suggested that this range provided eagles with a reliable food source each winter. Jackrabbit was the predominant food type (82%, N = 17) identified at feeding sites, and all carcasses were believed to have been provided by hunters.

Eagles typically perched on fenceposts west of Benmore Road and in junipers along the Vernon foothills in the northwest quarter of R5T9. Flight paths from the Vernon roost traversed this quarter and eagles often used perches here after leaving or before entering roosts. Eagles fed on only 1 carcass in this quarter and cattle grazing over most of the area probably limited food availability.

Eagle activity in the southeast quarter of R6T8 was similar to that in R5T9. Eagles perched on fenceposts or cottonwoods in flying to and from roosts. Eagles were seen feeding in this area on only two occasions, and although marked eagles perched in R6T8 for long periods of time (Table 5), foraging activity appeared to be limited.

The four remaining areas of high eagle use were located in the northeast portion of Rush Valley (Figure 24). Three quarters (R4T6 SE, R4T7 NE, and R3T7 NW) shared common borders and the fourth quarter was located in R5T5 SE. Eighteen percent of the total number of eagles seen and 9% of the total perch time were recorded in these areas. Eagles in the southeast quarter of R4T6 were usually seen west of State Highway 73. A group of ephemeral streams flowing southeast from the foothills of the Oquirrh Mountains divided the area into a series of hills overlooking the valley floor. Eagles fed on road kills along State Highway 73, but most carcasses were located within 3 km east of the access road to Tooele Army Depot. Eagles near carcasses in this area perched on the ground, but junipers were used at higher elevations east of Highway 73.

Eagle sightings in the northeast quarter of R4T7 were concentrated along the Pony Express Road. An abandoned fenceline 0.8 km south of a well in section 14 received consistent use and eagles frequently perched on earthen dams in the area. Feeding activity was noted on only 2 occasions, however, and this quarter did not appear to be a major foraging area.

In the northwest quarter of R3T7, most eagles were seen within 2 km of the railroad grade. This area was nearly devoid of fenceposts and junipers and nearly all eagles perched on the ground. It appeared that each winter some sheep suffered injuries and died following unloading in section 17; groups of 4-12 eagles were seen feeding on sheep carcasses there on 3 separate occasions.

The southeast quarter of R5T5 was the northernmost area of high eagle use in Rush Valley. Based on the movements of monitored birds, I believe this area was used most heavily by eagles roosting at Ophir. Eagles were also occasionally seen on the ground north of State Highway 73 feeding on jackrabbit carcasses. Jackrabbit was the only prey type identified here and fenceposts offered the best vantage points in the quarter.

Nocturnal Behavior

Roost Characteristics

Five roosts, 2 in canyons and 3 on valley floors, were identified in the study area by Edwards (1969) and Joseph (1977). Eight additional roosts, 7 in canyons and 1 on the valley floor, were discovered during this study. The precise location of 4 canyon roosts could not be determined due to their inaccessibility,.

The trees used by eagles at the Cedar Fort roost (Joseph 1977) could not be identified and a roost near Faust consisted of only a single juniper. Vegetative analysis was therefore restricted to the remaining 3 valley and 5 canyon roosts.

Vegetative structure and composition differed markedly between valley and canyon roosts (Table 6). Valley roost trees were all willow while canyon roosts were composed of a more diverse array of coniferous trees.

Stands of 11-15 willow trees characterized the 3 valley roosts. Average stand height varied from 15.0 m to 22.3 m (Table 6) and the distribution of castings and fecal material within these roosts suggested that all trees were used by eagles. Willow was the only tree found on the valley floor which exceeded 20 m and all valley roosts were in low moist areas associated with springs.

Based on observations at 2 roosts near Vernon, it appeared that eagles preferred to roost in the tallest trees available. Ekker's roost was composed of short trees and was least used. The similarity in average stand heights between the Marchant and Fairfield roosts suggested that eagles roosting on the valley floor preferred stands at least 20 m tall (Table 6) and these sites undoubtedly commanded the greatest visibility of the surrounding terrain.

Canyon roosts were typically located in sections of large continuous stands of coniferous trees. Density of trees over 10 cm DBH averaged 108 trees/ha and ranged from 65 trees/ha at 7 Mile to 138 trees/ha at Red Pine. Total basal area had a mean value of 13 m^2/ha and varied between 4m^2/ha to 19 m^2/ha. Basal area and height of roost

Table 6. Vegetative characteristics of roost sites in central Utah, December 1981 through March 1984.

	IMPORTANCE VALUES[a]							
Species	OPHIR	RED PINE	BLACK ROCK	7 MILE	GARDISON	EKKER	MARCHANT	FAIRFIELD
Douglas Fir (<u>Psuedotsuga menziesii</u>)	47	100	33		40			
White Fir (<u>Abies concolor</u>)	20		8		25			
Singleleaf Pinyon (<u>Pinus monophylla</u>)	7		54	100	16			
Utah Juniper (<u>Juniperus osteosperma</u>)	26		4		20			
Willow (<u>Salix spp.</u>)						100	100	100
Total Density (per ha)	126	138	103	65	107			
<u>Basal Area</u>								
Total (m^2/ha)	13	18	11	4	19			
Stand Avg. (m^2)	0.11	0.13	0.10	0.07	0.17			
Roost Avg. (m^2/ha)	0.2^b	0.3^c	0.3^b	0.2^b	0.3^b	0.6	1.4	1.3
<u>Height</u> (m)								
Stand Avg.	10.6	15.3	8.4	5.7	12.8			
Roost Avg.	13.9^c	24.0^c	15.4^c	5.7	21.9^c	15.0	20.1	22.3
Slope (%)	35	51	42	37	32			
Direction	315	350	360	0	30			

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[a] equals sum of relative density, relative basal area, and relative frequency divided by 3

[b] Significantly different from stand average (t-test, $p < 0.05$)

[c] Significantly diffent from stand average (t-test, $p < 0.001$)

trees were significantly higher than those of the surrounding stand at all canyon roosts (Table 6). Roost slopes were comparatively uniform, averaging 39%, and all faced north.

Species composition varied among canyon roosts. At Ophir and Gardison, Douglas fir was the dominant species and white fir (<u>Abies concolor</u>) and Utah juniper were subdominant. Red Pine roost was composed entirely of Douglas fir and 7 Mile was completely pinyon pine. The dominant species at Black Rock was pinyon pine followed by Douglas fir.

<u>Roost Behavior</u>. A total of 470 roosting locations on 22 radio-tagged eagles were gathered at 12 roost sites. Marchant and Ekker roosts were reclassified as a single site named Vernon because of their close proximity and regular interchange of roosting birds. Five roosts, 2 in canyons and 3 on valley floors, were not used at all by marked birds during at least one winter and were therefore excluded from yearly comparisons of roosting patterns.

Most eagles (78%, N = 74) used roosts closest to their last diurnal perches. Ophir was used most often (21%, N = 470) and eagles always roosted there when their last diurnal perch was closest to it. Vernon received the second greatest use (18%) but was not used on 10 occasions when it was closest to last perches. The distance to an alternate roost when Vernon was closest was farther than that between canyon sites and their alternate roosts (t test, $p < 0.02$).

Roost type (canyon or valley) also appeared to influence roost selection. Most (70%) marked eagles selected the roost closest to their last perch in the evening. Eagles using valley roosts were typically closest to them (94%, N = 32) but only about one-half of the eagles using canyon roosts were nearest to them (52%, N = 42). Eagles using canyon roosts often (65%, N = 20) bypassed closer valley roosts on their evening flights.

Windspeed and snowfall were two climatic variables associated with eagles using roosts that were not closest to their areas of diurnal activity. Wind speeds exceeded 32 km/hr on 4 of the 10 nights when Vernon was avoided. Two of these nights had greater than 5 cm of snowfall, and an additional 2 nights had heavy snowfall with no high wind. High winds were never noted on the 6 nights when canyon roosts were avoided. Precipitation did not occur on most nights (81%), or succeeding days (75%) when eagles used alternate roosts. Comparison of daily maximum and minimum temperatures to monthly averages on days of alternate roost selection yielded no significant differences between canyon or valley roosting birds.

The 7 consistently used roosts had significantly different numbers of radio-tagged individuals using them each year (Chi square, $p < 0.001$). Individual birds showed a variety of roosting patterns (Figures 25 - 27) suggesting a dynamic interchange between roosting populations. Canyon roosts were used more than expected during 1982 (Chi square, $p < 0.001$) followed by higher numbers of marked eagles at valley roosts during 1984 (Chi square, $p < 0.001$). Chi square analyses ($p < 0.01$) indicated shifts at Vernon, Deadman, Gardison, and Black Rock from 1982 to 1984. Vernon went from relatively low to high use while Black Rock and Deadman displayed the opposite trend

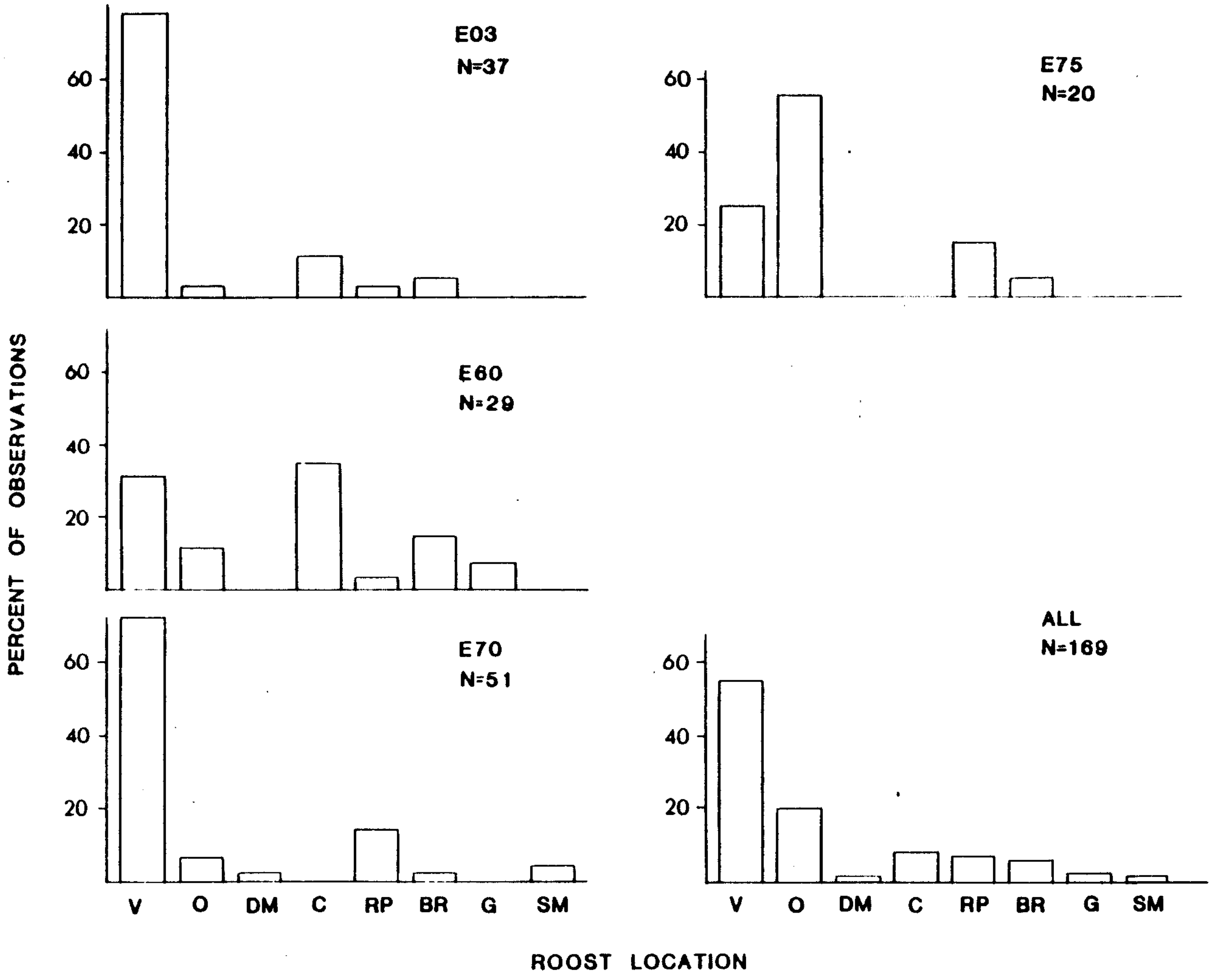

Figure 25. Relative use comparisons of major roosts by radio-tagged eagles and by all observations pooled near Rush Valley, UT, during1982. (V=Vernon, O=Ophir, DM=Deadman, C=Clover, RP=Red Pine, BR=BlackRock, G=Gardison, SM=Seven Mile)

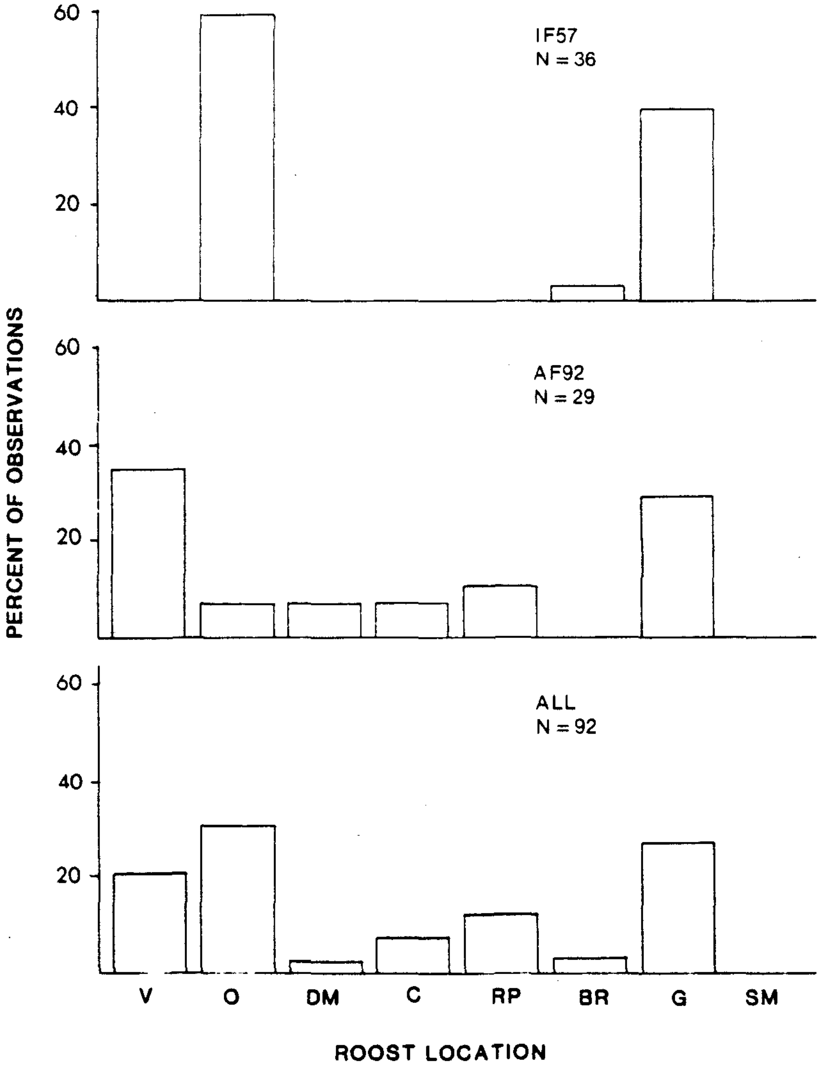

Figure 26. Relative use comparisons of major roosts used by radio-tagged eagles and by all observations pooled near Rush Valley, UT, during 1983; abbreviations as in Figure 25.

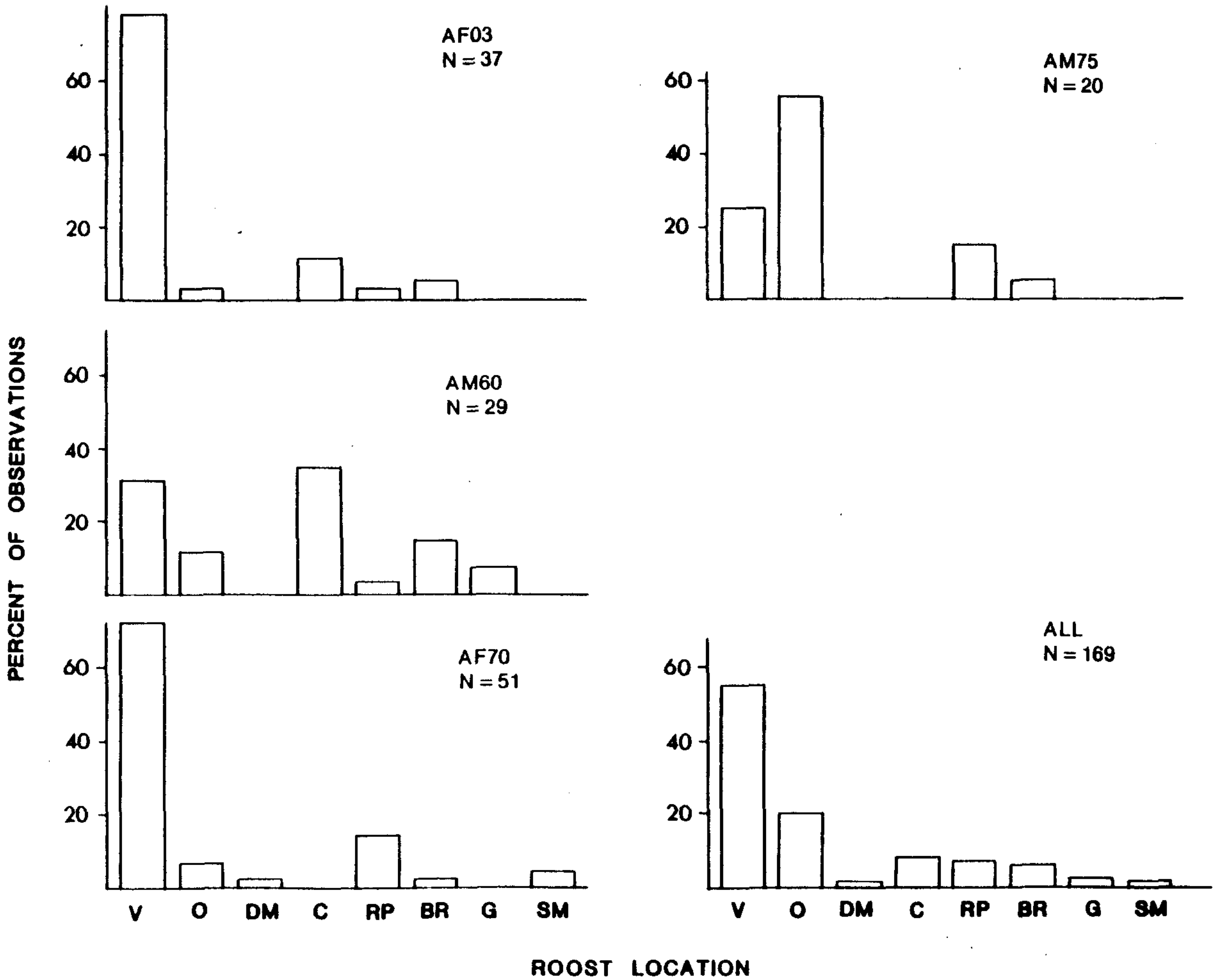

Figure 27. Relative use comparisons of major roosts by radio-tagged eagles and by all observations pooled near Rush Valley, UT, during 1984; abbreviations as in Figure 25.

(Figure 28). Gardison was used most during 1983 but had little use in any other year.

A monthly shift in the frequencies of eagles at valley and canyon roosts was also noted (Chi square, $p < 0.001$). Marked eagles used valley roosts more than expected during January and shifted to canyon roosts in March.

Eagles arrived later at and flew slower to canyon than valley roosts (t test, $p < 0.02$ and $p < 0.01$, respectively); no difference in departure times was noted between roost types. Eagles using canyon roosts flew farther than valley roosting birds to foraging areas (13.6 km and 5.3 km, respectively; t test, $p < 0.001$) (Figure 29) and carcasses (17.5 km and 6.7 km, respectively, t test, $p < 0.001$). Lastly, conspecifics were present more often at first perch and feeding sites of eagles roosting in canyons (Chi square, $p < 0.02$ for both).

Roost flight behavior varied between years. Average distance between roost and foraging areas varied annually (ANOVA, $p < 0.0001$) (Figure 30) and were significantly shorter in 1984 than in 1983 or 1982 (Scheffe test, $p < 0.05$ and $p < 0.01$, respectively). Roost arrival times became later each year (ANOVA, $p < 0.01$) and roost departure times were earlier in 1984 than in other years (t test, $p < 0.001$) (Figures 31 and 32, respectively).

<u>Roost Importance</u>. Eight roosts were used by marked eagles each winter and a total of 381 locations involving 22 marked individuals were included in the calculation of importance values. Roost importance values were stable between years at most roosts sites (Table 7).

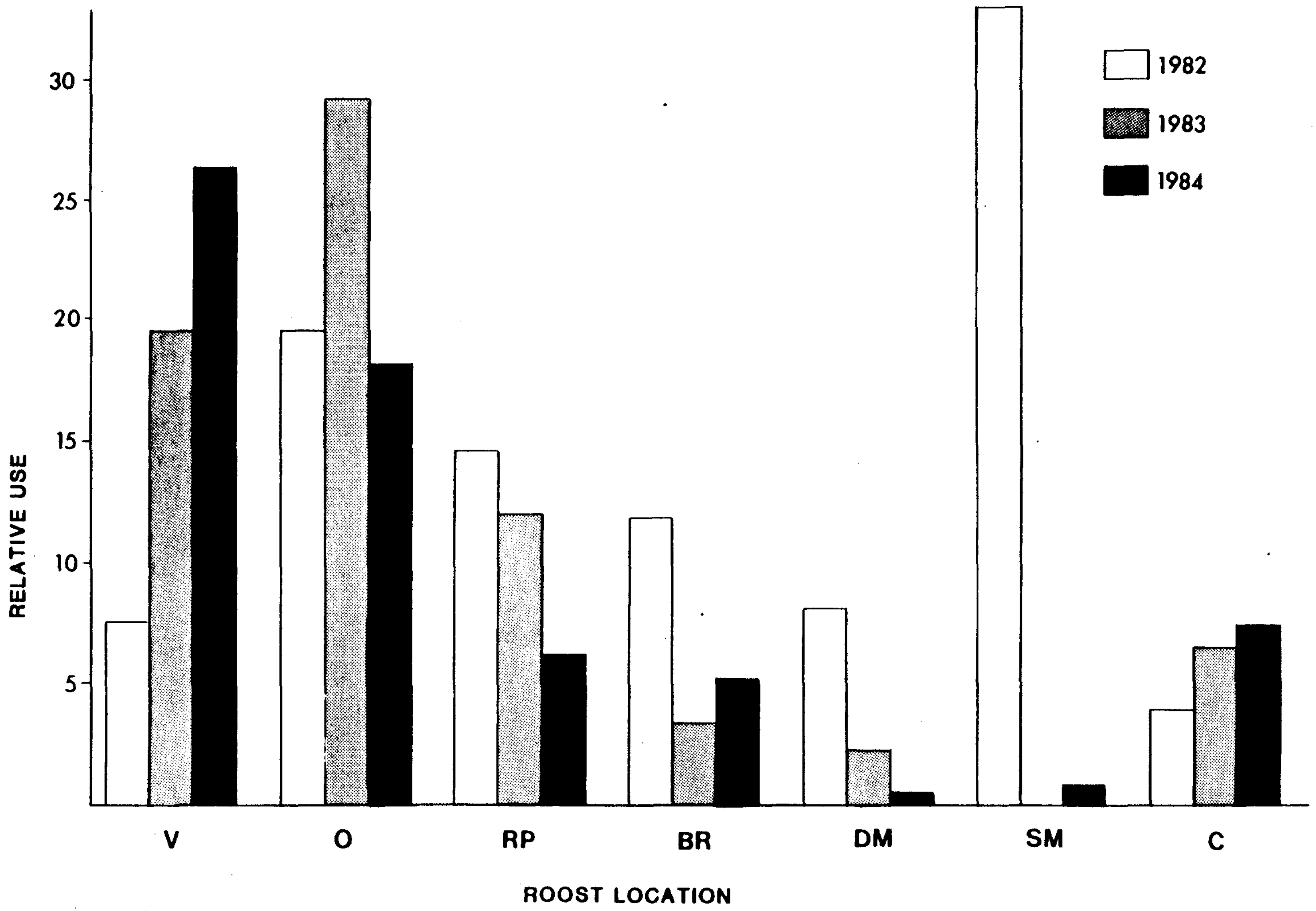

Figure 28. Relative use comparisons of major roosts near Rush Valley, UT, during 1982-1984; abbreviations as in Figure 25.

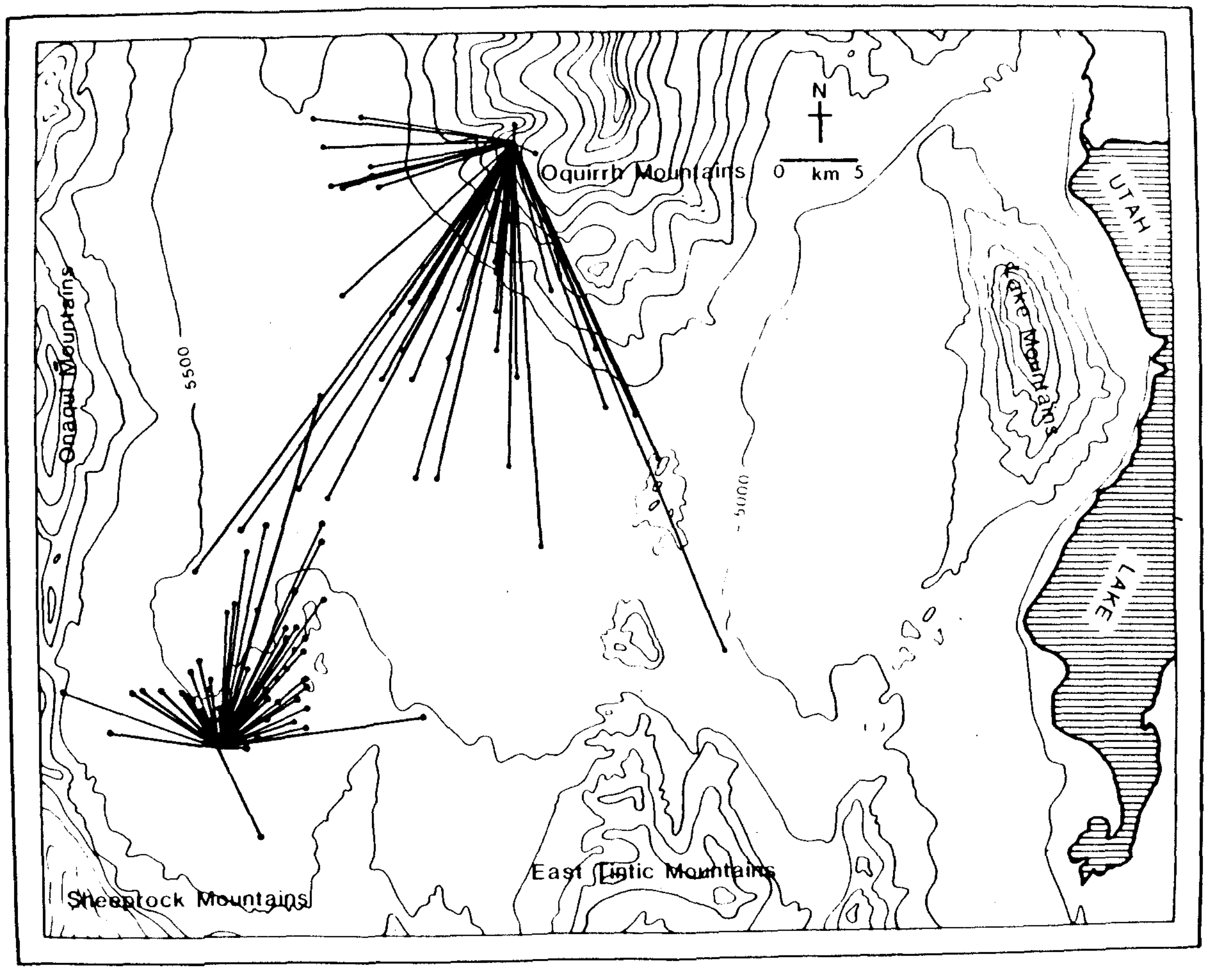

Figure 29. Distances and orientations of roost flights from Ophir (upper right) and Vernon (lower left) roosts, 1982-1984.

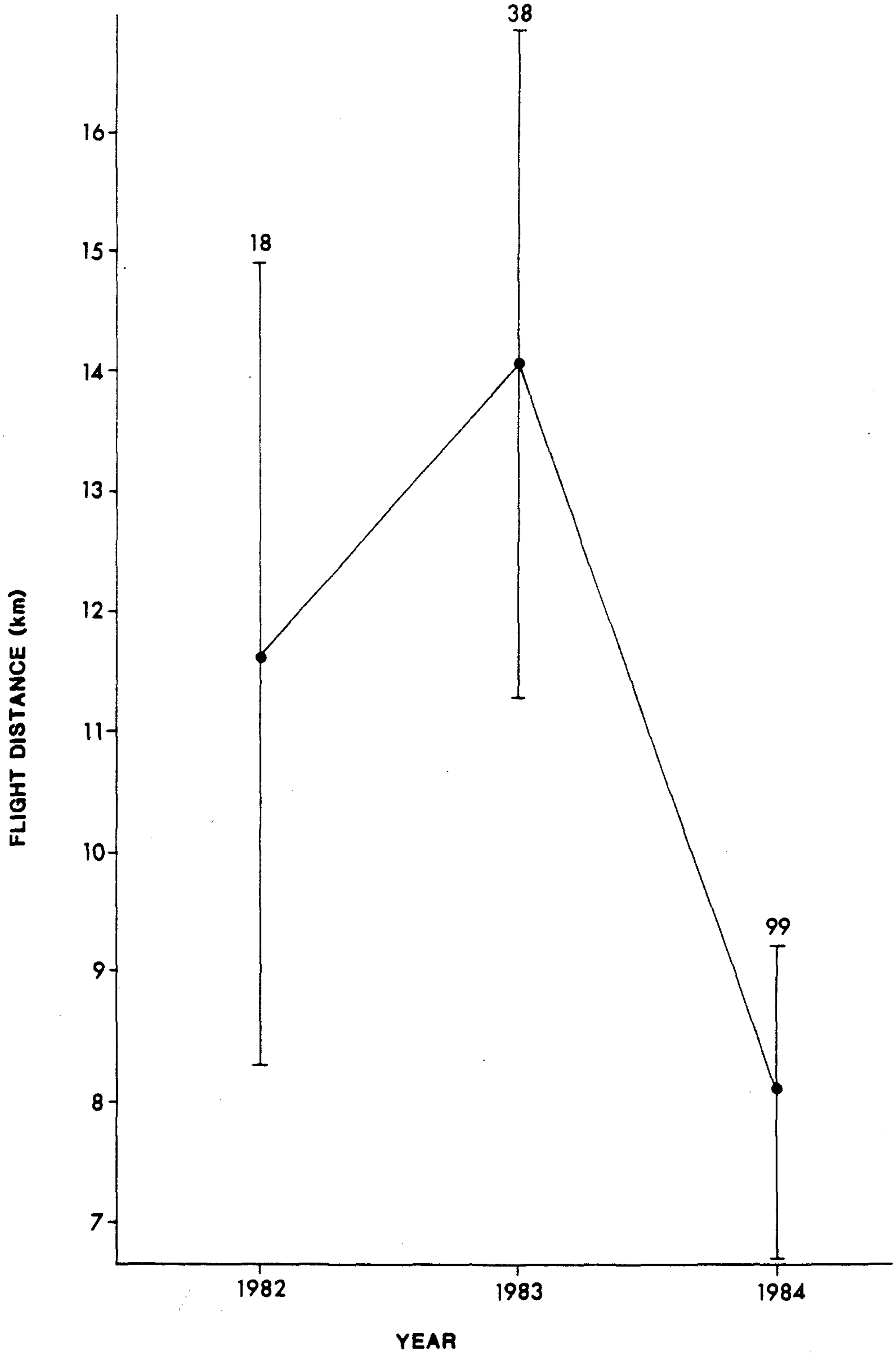

Figure 30. Comparison of mean roost-to-foraging area flight distances by year. Brackets represent 99% confidence intervals.

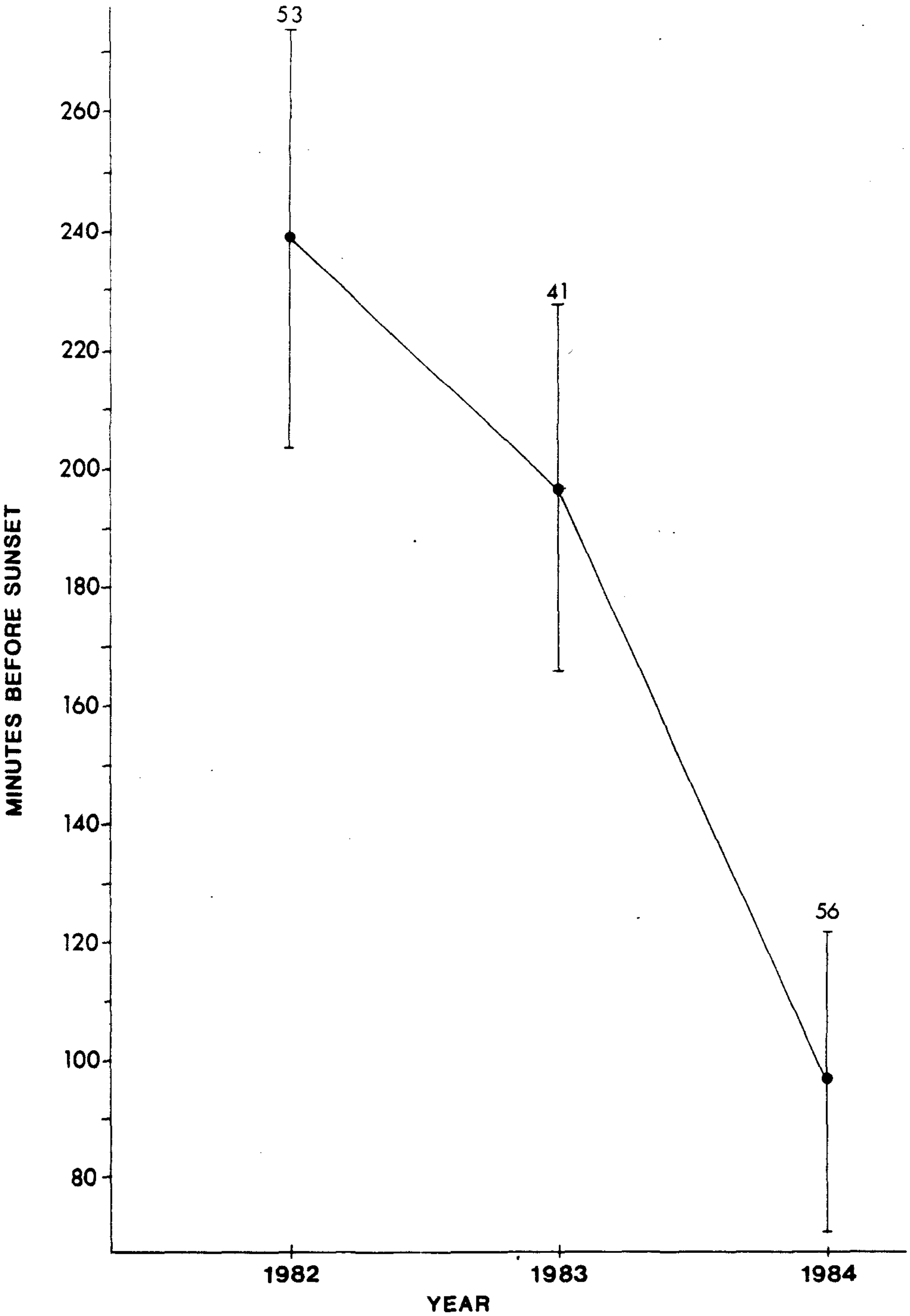

Figure 31. Comparison of mean roost arrivals by year. Brackets represent 99% confidence intervals.

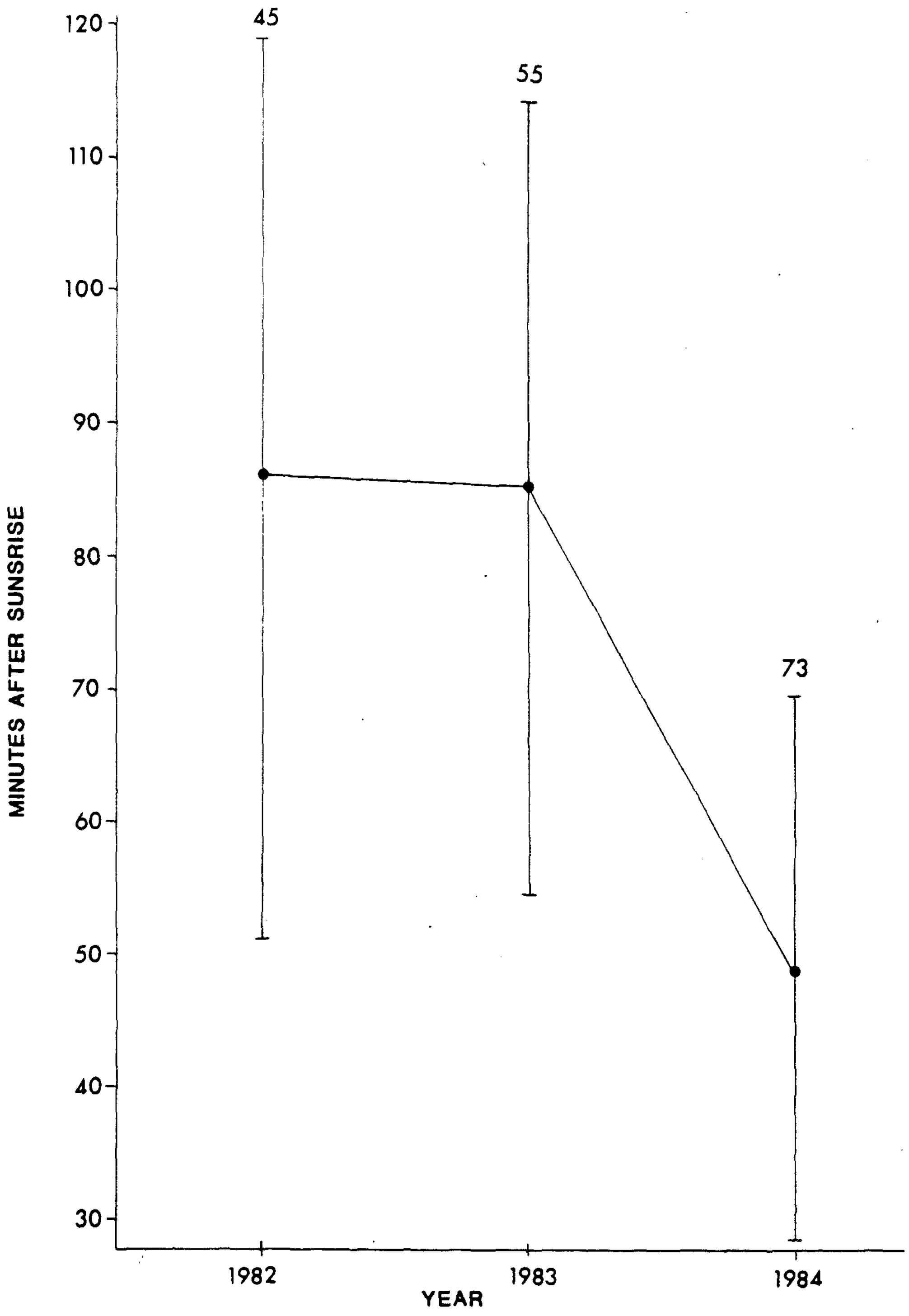

Figure 32. Comparison of mean roost departures by year. Brackets represent 99% confidence intervals.

Table 7. Comparison of importance values and ranks of roost sites used by 22 radio-tagged Bald Eagles in Rush Valley, Utah, January - March 1982-1984.

Roost	Average		1982		1983		1984	
	IV	Rank	IV	Rank	IV	Rank	IV	Rank
Vernon	25.0	2	15.0	3.5	17.5	3	36.5	1
Ophir	25.5	1	30.5	1	25.0	1	27.5	2
Deadman	5.0	7	12.0	5	3.5	7	2.5	7
Clover	11.5	4	7.0	6	11.0	5	9.5	5
Red Pine	13.5	3	18.5	2	16.0	4	12.5	4
Black Rock	11.0	5	15.0	3.5	6.5	6	13.5	3
Gardison	8.0	6	2.5	7	20.5	2	5.5	6

Ophir was the most important roost identified and it consistently ranked as an important site each year. Nearly all marked birds (N = 19) roosted at Ophir and eagles were found there on more nights than at any other roost. Over 40% (N = 256) of all canyon roosting locations were also recorded there.

Vernon ranked second in overall importance and ranked first in 1984. Excluding Ophir, more marked eagles (N = 13) used Vernon on more nights (N = 73) than any canyon roost. It was ranked at or above 3.5 for each year and was the only valley roost used during all 3 winters.

The remaining 5 canyon roosts received moderate to low use. Clover, Red Pine, and Black Rock received moderate use with about half of the radio-tagged population using each site. Eagles monitored at these 3 sites ranged from 27 nights at Clover to 40 at Red Pine. Importance values fluctuated widely at Gardison and Deadman indicating they were not consistently used. Both were located outside of Rush Valley and the distances from these 2 roosts to foraging areas may have limited their use.

Food Habits

Prey. In 1983, 287 castings were collected beneath roost trees at Vernon and 7 Mile, and 309 castings were collected in 1984 at Vernon, Faust, 7 Mile, Ophir, and Gardison roosts. A random sample of 20 castings from each roost during each year of collection was selected for analysis. All rabbit remains were assumed to be black-tailed jackrabbits although desert cotton-tailed rabbits (Sylvilagus auduboni) were occasionally seen in the foothills.

Mammals comprised over 94% (N = 142) of the prey remains identified in castings (Table 8). Black-tailed jackrabbit was the predominant species (85%); voles (Microtus spp.), domestic sheep (Ovis aeries), and mule deer (Odocoileus hemionus) were identified in low numbers. All castings containing vole remains were collected beneath trees where rough-legged hawks occasionally roosted. I was unable to distinguish between hawk and eagle castings and it seems likely that most (if not all) of the vole remains were from rough-legged hawks. Mallard (Anas platyrhynchos) was the only avian species identified and 2 castings were composed entirely of vegetative material. No significant change in food types was noted between 1983 and 1984 and the frequency of jackrabbit and sheep castings was similar to that reported by Platt (1976).

Bald eagles were never seen killing prey but 55 carcasses were identified that eagles were seen feeding upon. Jackrabbits were the most common prey item (65% of total) followed by sheep (15%), deer (3%), and cow (2%).

The difference between the frequencies of sheep seen during carcass observations and those found in castings (24% and 4%, respectively) was probably related to the large size of sheep carcasses. Sheep were the easiest carrion to identify during and locate after feeding observations. Smaller carcasses, the majority of which were probably rabbit, were often not identified because feeding eagles would have to have been disturbed to locate them. Casting

Table 8. Food items identified in 248 Bald Eagle castings collected beneath roosts in Rush Valley, 1983 - 1984.

	Minimum Prey Number		
	1983	1984	Total
MAMMALS			
Black-tailed Jackrabbit (*Lepus californicus*)	31 (79)[a]	89 (86)	120 (85)
Domestic Sheep (*Ovis aeries*)	-	6 (6)	6 (4)
Vole (*Microtus* spp.)	5 (13)	2 (2)	7 (5)
Mule Deer (*Odocoileus hemionus*)	-	1 (1)	1 (1)
BIRDS			
Mallard (*Anas platyrhynchos*)	2 (5)	5 (5)	7 (5)
Unidentified	1 (3)	1 (1)	2 (1)
TOTAL	39	103	142

[a] percentage of yearly total

analysis, on the other hand, may underestimate large prey types in eagle diets because the proportion of indigestible material (e.g. bones and hair) decreases with increased body size in mammalian prey. Any eagle feeding on a jackrabbit would ingest some fur or bones and would probably later egest a casting. It is conceivable, however, that some eagles could feed on a sheep carcass without forming castings, especially if there was access to central body cavity. The actual proportion of sheep in the diet of wintering bald eagles, therefore, is estimated at 7 - 15 % and only carrion was used.

Jackrabbit numbers appear to have been highest in 1982 and declined through 1983 and 1984. Prey transects provided evidence of population declines with significantly fewer rabbits being seen in 1984 than 1983 (means of 0.1 and 0.9 rabbits/km respectively, Mann Whitney, $p < 0.01$). Subjective assessments of rabbit numbers each January provided a conservative estimate of 2 - 3 times more seen in 1982 than 1983; rabbits were so scarce during 1984 that bait had to be acquired outside Rush Valley.

Foraging areas had significantly more rabbits and carcasses than random sites during 1983 (t test, $p < 0.001$ and < 0.01, respectively). In 1984, foraging areas had higher carcass numbers (t test, $p < 0.001$); only 4 rabbits were seen while walking prey transects but all were in foraging areas ($p < 0.01$).

Casting analysis and carcass observations indicated that black-tailed jackrabbit was the most important food source for eagles wintering in Rush Valley and sheep was the only other consistently used food type. Eagle foraging areas had the greatest number of live and dead jackrabbits, which strongly suggested that eagles are attracted to these sites because of their relative abundance of rabbits. Sheep carcasses, however, were typically located outside of foraging areas and sheep mortality appeared to be due principally to accidents during transport and severe winter weather. The occurrence of sheep carrion was, therefore, temporally and spatially unpredictable.

Feeding Behavior. Eagles appeared to fly directly from roosts to foraging areas. Roost sites of wintering eagles are usually close to foraging areas (Stalmaster and Gessaman 1982, Griffen et al. 1982, Keister 1981, Knight 1981) and since flights between these two areas are generally direct (Lish 1973, Knight 1981), I estimated distances between roosting and foraging areas by measuring the straight-line distance of monitored eagles from their morning roost to first diurnal perch. The mean distance from an eagle's first diurnal perch to its feeding site was only 5.8 km ($N = 31$) and eagles probably could easily see foraging activities of conspecifics within this radius.

Average time between roost departure and feeding was 197.3 min ($N = 38$), and 276.8 min ($N = 39$) elapsed between feeding and returning to roost. Roost departure and arrival times for feeding eagles were earlier than other eagles (t tests, $p < 0.02$ and $p < 0.01$, respectively). Flight speeds of feeding eagles to or from roosts, however, were not different from those of other birds. After feeding, eagles returned to the same roost 58% ($N = 40$) of the time and returned to the carcass on the following day 63% ($N = 19$) of the time.

Golden eagles, ferruginous hawks (Buteo regalis), and red-tailed hawks (Buteo jamaicensis) also winter in Rush Valley and may compete with bald eagles for food. Seven interspecific encounters involving adult bald eagles and 1 of the above raptors were noted. As far as I know, these are the only reported observations of agonistic interactions between bald eagles and golden eagles or ferruginous hawks.

We observed two interspecific encounters between bald and golden eagles near black-tailed jackrabbit carcasses during 1984. On 17 January an adult bald and an adult golden eagle were involved in an aerial confrontation 50 m above the ground. Both birds made several passes at one another, but no contact was made, and within 2 min both landed on the ground. Three min later the bald eagle flew directly at, dove, and struck on the back a second adult golden eagle perched on the ground 50 - 100 m away. A struggle ensued in which each bird struck the other repeatedly with open talons. Most attacks were initiated with short hops, but rushes along the ground were also seen. The encounter lasted nearly 1 min and ended when the golden eagle flew away. The bald eagle returned to the carcass site and dragged a freshly-killed jackrabbit to an area free of vegetation, but was supplanted by another adult bald eagle before feeding. Later, similar fights took place between several bald eagles that attempted to secure the carcass.

On 24 January an adult golden eagle was seen feeding on a jackrabbit while one adult bald and another golden eagle stood nearby. After 10 min the bald eagle supplanted the feeding bird with a short rush to the carcass. Seven min later the second golden eagle displaced the bald eagle by momentarily landing on its back with closed talons. The bald eagle responded by flying and landing about 5 m from the carcass. A third adult golden eagle, closer to the feeding site, faced the bald eagle and lowered its head each time the latter attempted to approach the carcass. Eight min later the bald eagle successfully supplanted the feeding eagle by flying to the carcass; all golden eagles flew away within 5 min after the bald eagle began to feed.

Overall, interspecific confrontations between eagles at feeding sites were rare. Golden eagles were seen at only 25% (N = 87) of the carcasses visited by bald eagles and were present less than 22% of the time (N = 239 hrs) at feeding sites of marked birds. Fewer golden eagles were seen at carcasses with bald eagles in 1982 (7%, N = 14) than in succeeding years (16%, N = 79) which suggested greater competition for food between these species in 1983 and 1984. Based on the incidents of 17 and 24 January, it appears that bald eagles may occasionally steal prey from golden eagles. This contrasts with the dominant position golden eagles appear to have in some bald eagle winter roosts (Lish 1973).

Encounters between bald eagles and raptors other than golden eagles were rare and only five incidents were observed during 1628 Hrs of observation. Although hawks were never seen near feeding eagles, 3 instances involving ferruginous hawks were probably motivated by food.

On 29 March 1983 an adult bald eagle attempted to kleptoparasitize adult ferruginous hawks on two occasions. The first began when the eagle flew directly at a hawk carrying an unidentified species of ground squirrel about 20 m above the ground. Upon intercepting the hawk, the eagle made four quick passes from 5 - 10 m above but made no contact. The hawk dropped the ground squirrel after the fourth pass and the eagle immediately flew to where the carcass fell but could not be seen on the ground. About 1 min later the eagle flew back to its original perch without the squirrel. Within an hour the same eagle pursued another ferruginous hawk carrying another ground squirrel. This apparent attempt at kleptoparasitism, however, was unsuccessful; the hawk remained above the eagle as both gained altitude and after several attacks from below, the eagle abandoned its pursuit.

I observed hawks attacking adult bald eagles on 3 occasions. On 18 February 1983 a ferruginous hawk stooped 3 times in broad, shallow arcs from roughly 30 m at a bald eagle standing on the desert floor. The eagle lowered its head during each pass but on the last pass also raised a wing, presumably to keep its balance, as the hawk passed within 1 m. The hawk then quit the attack and landed on the ground about 300 m away. Three min later the hawk made another stoop at the eagle which again responded by ducking its head. Although the eagle was not feeding, the presence of 5 common ravens and a northern harrier nearby suggested that a carcass may have been present.

Two attacks on a radio tagged adult bald eagle were initiated by hawks for no apparent reason. On 7 March 1983 an adult ferruginous hawk dove from about 50 - 80 m above a soaring bald eagle. The eagle eluded the attack by first swerving and then quickly landing. The hawk flew away after the incident and the eagle remained perched for another 50 min. The next day the same eagle was soaring at 100 - 150 m when it was attacked by an adult red-tailed hawk. The red-tail initiated the attack from 50 - 80 m above the eagle and displayed its talons during the dive. As the hawk passed the eagle rolled over and presented its talons but no contact was seen. Both birds then continued to soar and slowly drifted apart.

LeDuc (1970) saw a red-tailed hawk near its nest in Minnesota strike a bald eagle in flight. The encounters I observed were probably not directly associated with nest defense because they occurred over open desert far from any probable breeding sites. The onset of breeding behavior, however, may have prompted the hawks to attack; tolerance of large raptors, recognized as threats by hawks, may diminish during hawk breeding periods and lead to the type of attacks observed.

Climatic Factors

Comparison of Severity Index values between years indicated that winter conditions became more rigorous for bald eagles from 1982 to 1984 (Table 9). The mildest winter was in 1982 which had high temperatures (ANOVA, $p < 0.0001$) and fewer days of snow cover (Chi square, $p < 0.001$) than succeeding years. In 1983 temperature and snow cover values were intermediate and the most severe conditions were experienced in 1984 when significantly lower temperatures (ANOVA,

Table 9. Comparison of weather conditions in Rush Valley, UT, from 15 November to 31 March, 1982 - 1984.

	Year		
Variable	1982	1983	1984
Average Temperature	43.6	42.5	36.5
Days Below Freezing	19	12	37
Days with Snow Cover	56	74	109
Winter Severity Index	-912	-1094	3221

$p < 0.0001$) and more days of snow cover (Chi square, $p < 0.001$) were recorded.

The obvious disadvantage of increased thermoregulatory expenditures by bald eagles on cold winter days could have been compounded by other climatic factors in Rush Valley. Extended periods of snow cover concealed carrion which made it unavailable to foraging eagles. Hunters also may have had their access to hunting areas limited to sites adjacent to plowed all-weather roads during heavy snow cover. Carrion provided by hunters during these periods was concentrated near areas of high human disturbance which could have discouraged some eagles from feeding there. Assuming that bald eagles wintering in Rush Valley fed primarily on jackrabbit carcasses, low rabbit numbers coupled with cold temperatures in 1984 undoubtedly made this winter the most stressful to bald eagles during the study period.

Migration

In 1982, 5 eagles were located in northern areas during spring migration. Four were trapped in Rush Valley during January but the fifth was captured in Glacier National Park during autumn 1981 (McClelland, pers. comm.). Most of these eagles were females (N = 4) and 3 were immatures (Table 10).

The earliest location of a marked bird outside Rush Valley in 1982 was of an immature male (IM29) in the northeastern portion of the Great Salt Lake, UT. He was monitored there on 3 occasions from 4 March to 24 March near Willard and Ogden bays. On 1 July his

Table 10. Locations of migrating radio-tagged Bald Eagles monitored in Rush Valley, UT, during 1982.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
1. AF06, ADULT FEMALE				
13 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
12 Feb	last day monitored in Rush Valley, UT	40° 51' N 112° 11' W	near Bell Canyon in Tintic Mountains, UT	21
24 Mar	perched	41° 15' N 112° 18' W	near Ogden Bay, Great Salt Lake, UT	135
2. IF08, IMMATURE FEMALE				
19 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	--
25 Feb	last day monitored near Rush Valley, UT	40° 17' N 112° 44' W	6 km north of Dugway Proving Grounds, Skull Valley, UT	33
10, 24, Mar	perched	41° 01' N 111° 33' W	Devils Slide area of Weber Canyon, UT	130
7 Jun	radio location	61° 30' N 112° 34' W	mouth of Thubun River, Great Slave Lake, NWT	2150
9 Jun	perched	62° 30' N 112° 56' W	island in Francois Bay, Great Slave Lake, NWT	113

Table 10. continued.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
2. IF08, IMMATURE FEMALE (continued)				
21 Jun	radio location	61° 55' N 112° 46' W	Blanchet Island, Great Slave Lake, NWT	66
24 Jun	perched	61° 56' N 113° 36' W	most westerly island of Isles Basses, Great Slave Lake, NWT	44
3. IF27, IMMATURE FEMALE				
15 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
27 Jan	last monitored in Rush Valley, UT	40° 15' N 112° 27' W	roost near Vernon, UT	4
10 Mar	flying, perched	41° 27' N 111° 01' W	Nuponsett Reservoir, south east of Woodruff, UT	208
24 Mar	perched	41° 40' N 111° 31' W	southwest of Randolph, UT	24
15 May	flying, perched	61° 37' N 111° 41' W	east arm of Thubun Lake, NWT	2132
17 May	perched	61° 36' N 111° 47' W	near shore of Thubun Lake, NWT	5

Table 10. continued.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
3. IF27, IMMATURE FEMALE (continued)				
18 May	flying	61° 55' N 112° 07' W	Hornby Channel, Great Slave Lake, NWT	41
17 June	flying	61° 35' N 110° 12' W	Taltson Lake, NWT	116
20 June	radio location	63° 00' N 109° 48' W	near Bigstone Point, Great Slave Lake, NWT	160
4. AM29, ADULT MALE				
21 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
20 Feb	last monitored near Rush Valley, UT	40° 03' N 112° 35' W	Red Pine Roost, UT	18

Table 10. continued.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
4. AM29,	ADULT MALE (continued)			
4 Mar	perched, flying	41° 37' N 112° 15' W	near Willard Bay, UT	163
10, 24 Mar	flying	41° 15' N 112° 18' W	near Ogden Bay, UT	20
1 Jul	recovered transmitter	61° 28' N 110° 50' W	Rutledge Lake, NWT	3075
5. AF50,	ADULT FEMALE			
15 Jan	first monitored near	40° 12' N 112° 09' W	roost in Thorpe Hills, UT	520
7-14 Apr	nesting	60° 38' N 109° 55' W	Hill Island Lake, NWT	3180

transmitter was recovered near Rutledge Lake, Northwest Territories (NWT). The Ogden Bay area was also the only known area used by an adult female (AF06) during migration and she was located there on 24 March.

The 2 remaining immature females used mountainous areas east of the Great Salt Lake during their migrations. On 10 March IF27 was located at the Nuponsett Reservoir in northeastern Utah; the other female on this date was perched in Weber Canyon and was still there on 24 March. By 24 March, IF27 had moved northeast to an area near Randolph, UT; she moved to her summering grounds near the Great Slave Lake, NWT, by mid June and was last located on 20 June in the lake's eastern areas. The remaining immature female (IF08) was located in this same general area from at least 7 June until 20 June.The adult female trapped in Glacier National Park was first located in Rush VAlley on 17 January. She was never located during spring migration but was found nesting near Hill Island Lake, NWT on 7 April; 1 young fledged from this nest.

Migrational data were recorded on 4 of the 7 eagles outfitted with radios in Rush Valley during 1983 (Table 11). There were 2 adult males, an adult female, and an immature female. Another eagle, tagged in Glacier National Park, MT, spent a few days in the study area during March and was also followed north.

The only locations in Utah during migration in 1983 were provided by the immature female (IF57). On 1 April she was seen near Willard Bay but had left by 5 April when she was monitored soaring north above

Table 11. Locations of migrating radio-tagged Bald Eagles monitored in Rush Valley, UT, during 1983.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
1. AM07, ADULT MALE				
28 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
9 Feb	left Rush Valley, UT	40° 06' N 112° 25' W	near Vernon, UT	
11,12, 17 Jun	perched	61° 53' N 112° 00' W	Union Island and vicinity, Great Slave Lake, NWT	2340
18 Jun	perched	61° 52' N 111° 58' W	island south of Union Island, Great Slave Lake, NWT	4
2. AU23, ADULT (Trapped in autumn 1982, Glacier National Park, MT)				
21 Mar	first monitored near	40° 00' N 112° 52' W	near Simpson Springs, Skull Valley, UT	570
23 Mar	last monitored near Rush Valley, UT	40° 03' N 112° 25' W	Red Pine roost, UT	26

Table 11. continued

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
2. AU23, ADULT (Trapped in autumn 1982, Glacier National Park, MT)				
1 Apr	flying	45° 02' N 111° 39' W	along Madison River between Hebgen and Ennis Lakes, MT	570
7 Apr	flying	48° 55' N 111° 25' W	along Alberta-Montana border, southeast of Lethbridge, Alberta	430
1 May	flying	56° 04' N 109° 54' W	west of Peter Pond Lake and near Saskatchewan - Alberta border	790
9 July	transmitter probably molted	56° 26' N 107° 50' W	between Porter and Frobisher lakes, 64 km nw of Buffalo Narrows, Saskatchewan	130
3. IF57, IMMATURE FEMALE				
28 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-

Table 11. continued

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
3. IF57, IMMATURE FEMALE (continued)				
28 Mar	departed Rush Valley, UT	40° 06' N 112° 25' W	near Vernon, UT	-
1 Apr	perched, flying	41° 40' N 112° 14' W	near Willard Bay, UT	145
5 Apr	flying	41° 45' N 111° 45' W	above Logan Canyon, UT	55
15, 17, June	perched	63° 29' N 116° 24' W	on nest near small lake near Emile River, NWT; 34 km south of nest of 165.94	2985
4. AF92, ADULT FEMALE				
13 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
27 Mar	departed Rush Valley, UT	40° 06' N 112° 25' W	near Vernon, UT	-
15 Apr	flying	52° 53' N 110° 00' W	near Alberta-Saskatchewan border, east of Wainwright, Alberta	1496

Table 11. continued

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
4. AF92, ADULT FEMALE				
16 Apr	flying	53° 37' N 110° 00' W	near Alberta-Saskatchewan border, north of Lloydminster, Alberta	80
9 July	brooding young	57° 30' N 106° 16' W	nest on Morrison Island, Cree Lake, Saskatchewan	469
5. AM94, ADULT MALE				
14 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
27 Jan	flying; last day monitored in Rush Valley	40° 10' N 112° 33' W	near Onaqui Mountains, UT	12
4, 6, 9 Mar	perched	45° 30' N 110° 35' W	along Yellowstone River, 25 km south of Livingston, MT	625
29 Mar (1300 hrs)	flying	46° 22' N 111° 30' W	south end of Canyon Ferry Reservoir, MT	118

Table 11. continued

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
5. AM94, ADULT MALE (continued)				
29 Mar (1500 hrs)	flying	47° 01' N 112° 00' W	along MissouriRiver, MT	79
31 Mar	flying	48° 30' N 113° 13' W	between Glacier National Park and Browning, MT	191
13, 15 17 Jun	incubating	63° 47' N 116° 47' W	near small lake near Emile River, NWT	1671

Logan Canyon. By 15 June she was nesting near a small lake along the Emile River, NWT.

The adult female (AF92) was seen soaring north near Wainwright, Alberta on 15 April and continued to move north past Lloydminster, Alberta on 16 April. The next location was on 7 July where she was found brooding young at a nest on Morrison Island, Cree Lake, Saskatchewan.

From 4 March to 9 March, an adult male (AM94) was sighted along the Yellowstone River near Livingston, MT. He was soaring north on 29 March on passed near Canyon Ferry Reservoir and Holter Lake, MT. He was still moving north on 31 March when he entered Canada between Glacier National Park and Browning, MT. On 13 June he was nesting near a small lake along the Emile River which was only 35 km from the nest of IF57.

Only 1 location was discovered on the remaining male in 1983. The same segment of the Yellowstone River used by AM94 was used by AF92 from 6 March to 9 March. This male (AM07) was seen from 11 June to 18 June on summering grounds near Union Island in the Great Slave Lake.

The remaining eagle was radio-tagged in Glacier National Park and was located in Skull Valley on 21 March and left the study area on 23 March. On 1 April, it was located soaring north along the Madison River, MT and by 7 April it had moved nearly straight north to the Montana - Alberta border. It had moved northeast to an area near Peter Pond Lake along the Alberta - Saskatchewan border by 1 May. The transmitter was located on 9 July between Porter and Frobisher lakes, Saskatchewan. The site was nearly due east of that of 1 May and the transmitter had probably been molted.

Only 3 of 14 eagles radio-tagged during 1984 were located after leaving Rush Valley (Table 12). All were adults and, unfortunately, all were eventually found dead. The only known site used by AF09 during spring migration and she was found perched near Chain Lake Reservoir, Alberta. She was found dead at Thubun Lake, NWT on 20 July. On 22 July, AM60 was found dead in Defeat Lake, NWT, and AM75 was lying along the shore of Marion Lake, NWT on 24 July. The condition of all three eagles led investigators to believe they had been dead for several months.

Table 12. Locations of migrating radio-tagged Bald Eagles monitored in Rush Valley, UT, during 1984.

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
1. AF09, ADULT FEMALE				
14 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
8 Feb	last day monitored in Rush Valley, UT	40° 17' N 112° 10' W	near Manning Canyon, UT	30
3 Apr	perched	50° 06' N 114° 10' W	7 km south of Chain Lake Reservoir, Alberta	1796
20 Jul	dead	31' N 112° 02' W	along shore ofThubun Lake, NWT	503
2. AM60, ADULT MALE				
2 Jan	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
13 Feb	last day monitored near Rush Valley,UT	40° 01' N 112° 13' W	Black Rock Canyon, UT	21
22 Jul	dead	62° 19' N 113° 41' W	in water, Defeat Lake, NWT	2532

Table 12. continued

Date	Behavior	Location Latitude/Longitude	Description	Distance (km) from previous location
3. AM75, ADULT MALE				
30 Dec	transmitter attached	40° 06' N 112° 25' W	near Vernon, UT	-
23 Feb	last day monitored in Rush Valley, UT	40° 22' N 112° 15' W	near Ophir Canyon, UT	32
24 Jul	dead	63° 03' N 116° 20' W	along shore of Marion Lake NWT	3107

DISCUSSION

Factors Influencing Eagle Behavior

Diurnal. Most bald eagles perched on the ground because higher perches were limited in central Utah. Junipers were used when available but competition for these perches seldom resulted in more than 2 eagles in the same tree. Similar perching patterns have been reported in central Nevada (Page and Miller 1981) and Colorado (Harmata 1984) but these patterns are in direct contrast to the routine use of deciduous trees in more riparian habitats (Southern 1963, Shea 1973, Jonen 1973, Steenhof et al. 1980, Knight 1981). Deciduous trees were rare in Rush Valley and were located far from foraging areas. Bald eagles used deciduous trees principally for roosting and occasionally for loafing. Diurnal habitat selection by eagles wintering in arid areas appears to be based, therefore, on different criteria than those in aquatic ecosystems.

Perch type was positively correlated with perch duration and probably also influenced diurnal habitat selection. Visibility becomes more restricted with decreasing perch height and bald eagles near the ground were probably more sensitive to disturbances than those perched higher. Eagles on the ground appeared to compensate for this by selecting elevated areas. Ridgetops at foraging sites were consistently used and probably commanded the most favorable view of surrounding areas.

Jackrabbit was the main food found in bald eagle castings and at feeding sites. This is supported by earlier studies (Edwards 1969, Platt 1976, Joseph 1977) and suggests that jackrabbit numbers have an important influence on winter bald eagle population size in the study area. Platt (1976) believed that highway vehicles were responsible for providing road-killed rabbits for eagles. This is not supported by my data, as nearly all carrion was found in open desert and gravel was seldom found in castings. Deer and sheep were eaten sporadically, depending on availability, but horse (_Equus_ _caballus_) carcasses were never fed upon.

If bald eagles capture live prey in Rush Valley, it must be a rare event. Not a single bald eagle kill was confirmed during the 3 winters of this study. Joseph (1977) and Edwards (1969) believe that adults are active predators and may even hunt communally. It is my opinion that most of the wintering population relies on scavenging with carrion primarily supplied by hunters.

Rabbit numbers declined from 1982 to 1984. Yearly fluctuations in population levels may follow a 10 yr cycle in the West (Gross et al. 1974). Annual counts in Rush Valley by the U.S. Army indicated peak jackrabbit numbers during Fall 1980, followed by steady declines through 1985 (R. LeClerc, pers. comm.) Reduction in rabbit numbers was further quantified by prey transect data during 1983 and 1984.

Prey densities were higher in eagle foraging areas than in other areas of the valley. I believe prey availability was the principal criterion used by bald eagles in selecting diurnal habitat. Competition for food at these sites, in turn, had a direct impact on regulating population size. By contrast, Edwards (1969) contended that there is little correlation between jackrabbit and eagle numbers. His research was conducted during a period of peak jackrabbit numbers, however, and did not involve a quantitative study of the effects of prey availability on eagle behavior.

Each winter the diurnal activities of marked eagles were usually concentrated in 1 or 2 areas on the valley floor. The Vernon drainage was most consistently used and was within 7 km of the Vernon roost; feeding sites south of Ophir were within 12 km of that roost. High prey numbers and importance values in foraging areas near roosts suggested that bald eagles select roosts as close as possible to sites with reliable food sources.

Most marked eagles showed longer term use of diurnal areas than communal roosts and fidelity to diurnal sites appeared to be unrelated to roosting behavior. This pattern was best seen in 1983 when AF92 (Figure 33) used 7 different roosts but only 1 area for diurnal activity. Similar patterns were seen among adult females and males during 1984 (Figures 34 and 35, respectively). IF57, the only immature, exhibited the most diffuse perching pattern (Figure 33). Foraging efficiency is generally believed to be lower among subadults (Erskine 1968, Griffen 1981, Fischer 1982, Stalmaster 1984) and the wide ranging behavior of immatures may have been due to competitiion with a principally adult wintering population. The perching pattern of IF57 could also reflect explorations of the wintering area by a naive resident.

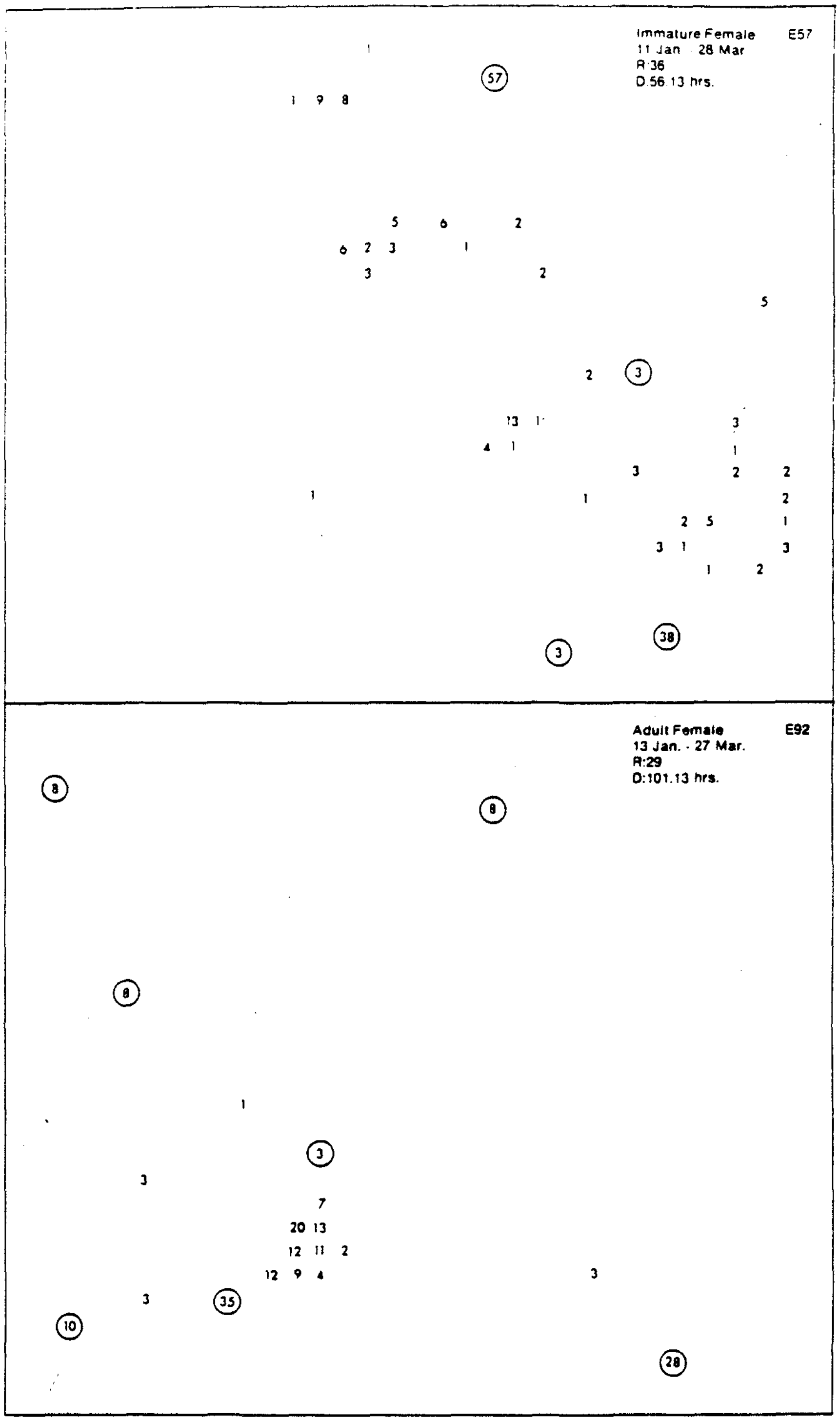

Figure 33. Distribution of diurnal sightings of transmitter-equipped Bald Eagles in 1983. Numbers represent percentage of time (D) eagles perched within a 0.28 km^2 square. Relative roost use (circled number) and minimum residence time in days (R) are also listed.

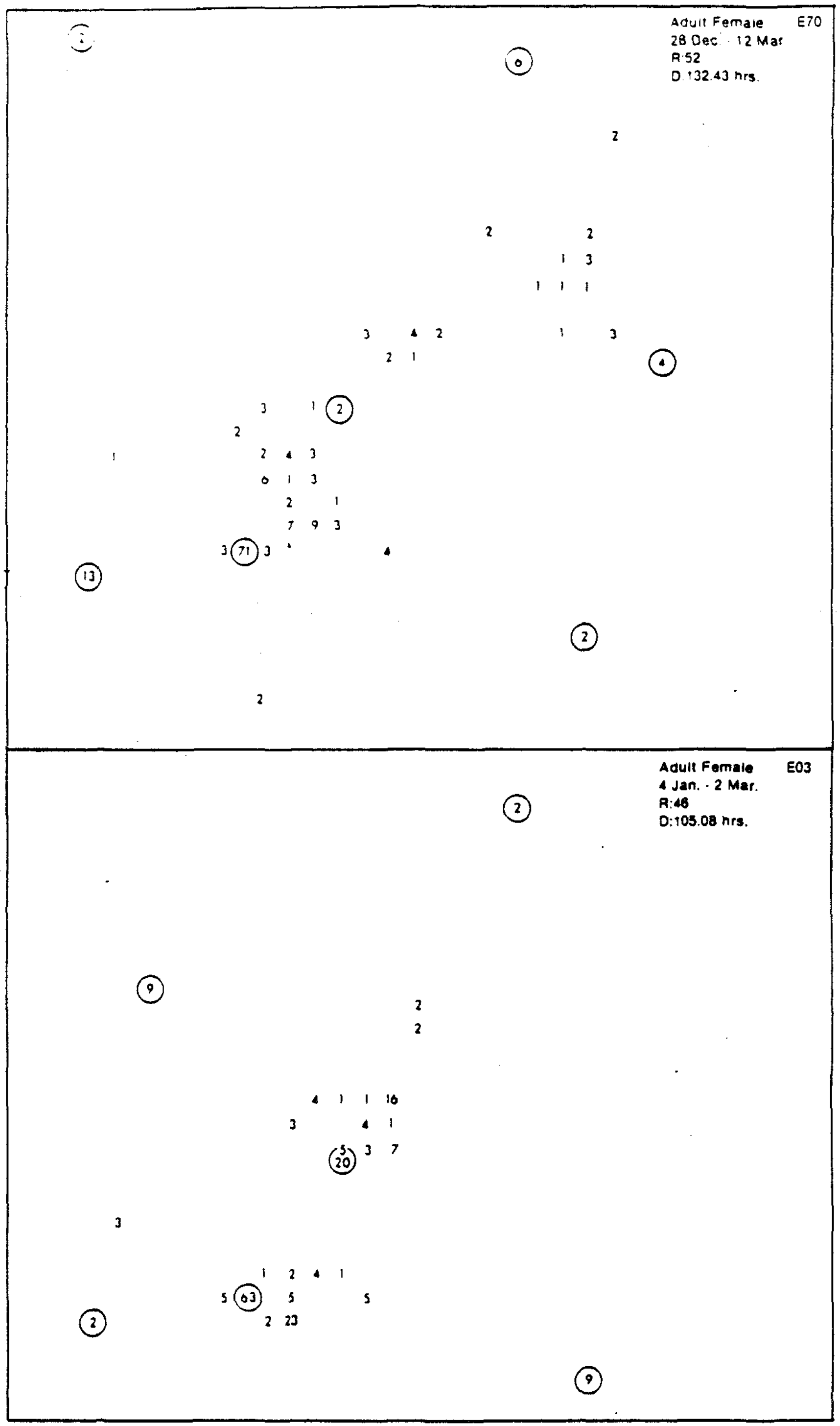

Figure 34. Distribution of diurnal sightings of transmitter-equipped Bald Eagles in 1984. Numbers represent percentage of time (D) eagles perched within a 0.28 km^2 square. Relative roost use (circled numbers) and minimum residence time in days (R) are also listed.

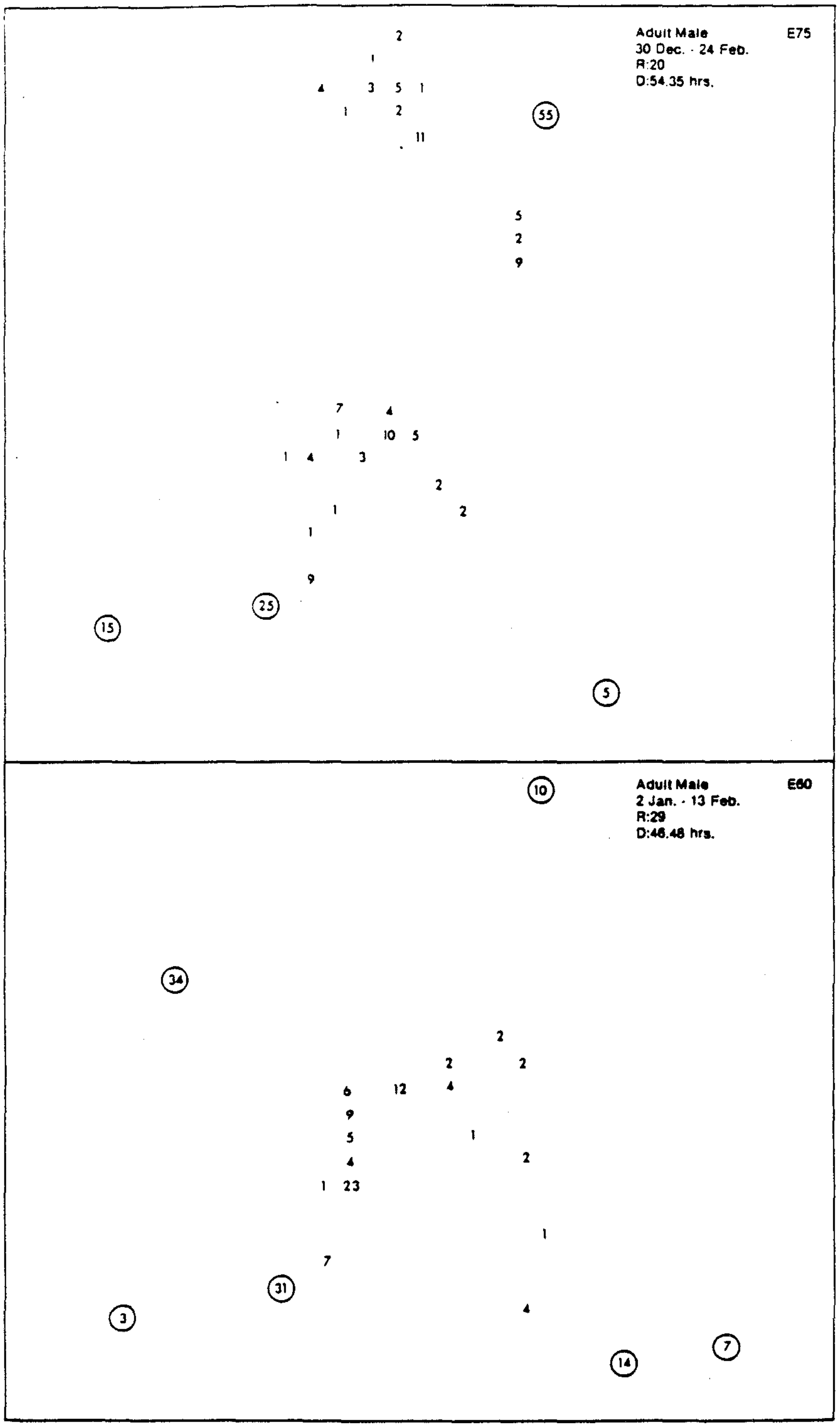

Figure 35. Distribution of diurnal sightings of transmitter-equipped Bald Eagles in 1984. Numbers represent percentage of time (D) eagle perched within a 0.28 km^2 square. Relative roost use (circled numbers) and minimum residence time in days (R) are also listed.

Morrison and Caccamise (1985) reported similar patterns of diurnal and nocturnal habitat use among starlings (Sturnus vulgaris). Many starlings showed more fidelity to feeding areas than to roosts. These authors propose that diurnal areas are centers of activity and roosts are of secondary importance. Nocturnal concentrations form in acceptable habitat that is as close as possible to these "diurnal activity centers."

Experience with feeding areas can influence feeding efficiency by reducing the time necessary to find food (Hamilton and Gilbert 1969). Davis (1975) discovered that gulls used very restricted feeding ranges and seemed to ignore other opportunities close by; he suggested that intraspecific competition led to this type of foraging. Gulls are thought to have compensated for the possible energetic benefits of closer feeding sites by maximizing foraging efficiency at familiar ones.

This could also apply to the regular use of feeding areas by bald eagles. Individuals regularly frequenting an area develop confidence in foraging there because of familiarity with it. If regular sources of food are available, experience would permit insight as to where and when carcasses may be available; familiarity could also translate into a dominant feeding position at carcasses found there. Bald eagles in Rush Valley appeared to follow a similar strategy, especially during periods of low prey availability.

Feeding efficiency is one of the most important factors influencing the survival of wintering eagles. Cooperative hunting is cited by Edwards (1969) as a means by which bald eagles increase their foraging efficiency in Rush Valley. No cooperative hunting was observed during this study but there were a variety of behavioral mechanisms that bald eagles could have used to communicate the location of food.

Ravens were almost always present at carcasses and undoubtedly provided the major mode of interspecific communication to bald eagles. Ravens gathered at a carcass were conspicuous by their numbers, and disputes over bits of food were easily recognized. It took ravens relatively long periods of time to secure sizable amounts of food on their own because they lacked the anatomical features needed to dismember carcasses. Ravens appeared to initially rely on raptors to open carrion, then stole and ate small scraps which were left undefended. Ravens were nearly always present at trap sites and were consistently seen at eagle feeding sites. Many ravens at a carcass may have lowered the probability of feeding eagles being disturbed because of their enhanced ability to detect danger.

Turner (1964) reported that subadults were most strongly attracted to feeding birds; this may be particularly important to bald eagles. Young eagles with limited hunting skills probably used the behavior of ravens and feeding eagles to help them locate food.

Interspecific communication has been proposed as a means of increasing foraging success in a variety of birds. The black vulture (Coragyps atratus) are believed to use turkey vultures (Cathartes aura) and dogs (Canis familiaris) to locate carrion (Stewart 1979). Foraging behavior was seen across species in mixed heron flocks (Caldwell 1981). Conner et al. (1975) reported that the american crow

(Corvus brachyrhynchos) had to be present at garbage dumps before ravens would land and that crows responded to raven alarm calls. Woodpeckers also respond to alarm calls of other birds in mixed winter feeding flocks (Sullivan 1984).

Local enhancement is defined as attraction caused by one individual on other members of the group (Hinde 1970). I believe local enhancement was operating at carcasses because of the mechanics of eagle feeding. Eagles first land on carrion and use their talons to secure it. They then bite into the body and rip flesh free by lifting the head. The lowering and raising of a feeding eagle's head provided an alternating unintentional signal on carcass location. White, contrasting with black, is presumably the most conspicuous plumage (Armstrong 1970, Kushlan 1977, Caldwell 1981, Erwin 1983) and the feeding activity of an adult bald eagle is probably easily detected by other birds in the area. Knight and Knight (1983) reported the rate of head raising among feeding bald eagles increased with greater eagle numbers and proposed that a raised head deters piracy and supplanting attempts. Feeding eagles could therefore have communicated information on carrion location and the likelihoood of feeding there to other conspecifics nearby.

The presence of conspecifics has been reported to increase the foraging efficiency of a variety of birds. Wood pigeons have higher recruitment rates with larger feeding flock sizes (Murton et al. 1966). Large flocks of ardeids indicate areas of high prey density (Krebs et al. 1972, Kushlan 1977, Hafner et al. 1982). Large wintering concentrations of bald eagles at areas with high prey abundances are well documented (Southern 1963, Retfalvi 1965, Jonen 1973, Lish 1973, Harmata 1984) and there appears to be little doubt that bald eagles use the number and behavior of conspecifics in obtaining food.

The number of eagles at a feeding site influenced the probability of other eagles finding it. Large groups were most easily seen but agonistic encounters among bald eagles increase with increasing group size (Stalmaster and Gessaman 1982). Small groups raised the chance of each bird obtaining some food but more time was spent looking for danger while feeding (Knight and Knight 1983). Group size was therefore a compromise between these and other selective factors such as prey availability, foraging efficiency, and social status.

Eagles were initially attracted to a site by the behavior of ravens or conspecifics. Decisions to remain at a site were probably based on trial and error, and, behavior was continually modified as eagles arrived and left. Individuals who found that their probabilities of feeding were high stayed while others left.

Group size appeared to have been limited by interspecific interactions at carcasses. In spite of declining prey availability from 1982 to 1984, eagle numbersat carcasses remained constant (Chi square, NS) and no difference in group sizes was seen at jackrabbit and sheep carcasses (t test, NS). Agonistic encounters, however, did appear to increase with decreasing food availability. Klem et al. (1985) described a series of observations where raptors killed other raptors. They proposed that such encounters were initiated by self-defense, territorial defense, or predation. My observations suggest that defense of food and attempts at kleptoparasitism also lead to interspecific confrontations in raptors and that the frequency and severity of such encounters appear to be related to food availability.

Nocturnal. Roosting patterns of marked eagles indicated movement of the wintering population between roosting sites. The most significant influence on roost selection appeared to be proximity to foraging areas. Prey availabilty has been considered the major influence in determining roost location for a number of raptors (Weller et al. 1955, Gurr 1968, Bildstein 1979, Stewart 1979, Barrows 1981, Craig and Craig 1984). Bald eagles occasionally roost where they feed (LaBonde 1981, Griffen et al. 1982) but generally select sites with acceptable habitat characteristics that are as close as possible to feeding areas (Jonen 1973, Shea 1973, Steenhof et al. 1980, Fischer et al. 1981, Keister and Anthony 1983). Harmata (1984) believed that movements between upland and riparian roosts in San Luis Valley, CO, were caused by shifting availabilities of terrestrial and aquatic prey. In Rush Valley, Edwards (1969) proposed that roosts nearest hunting areas were used most often and disturbances at feeding sites led to changes in roosting patterns.

Decreasing food availability from 1982 to 1984 probably led to the shifts in roosting patterns among marked birds. Inactivity has been proposed as an important winter survival strategy in bald eagles (Stalmaster and Gessaman 1982) and distances between roosting and foraging areas would therefore be predicted to be as short as possible.

Eagles may have responded to declining prey abundance by using roosts closer to foraging areas. Roost sites of wintering eagles are usually close to foraging areas (Keister 1981, Knight 1981, Griffen et al. 1982, Stalmaster and Gessaman 1982) and since flights between these two are generally direct (Lish 1973, Knight 1981), I estimated distances between roost and foraging areas by measuring the straight-line distance of monitored eagles from morning roosts to their first perch locations. The use of first perches as an indicator of foraging areas is supported by the short distance (x = 5.8 km, N = 31) between first perch locations and subsequent carcass feeding locations. The distance to and from roosts to feeding sites was significantly longer in 1982 and 1983 than in 1984.

Most marked eagles used canyon roosts during 1982 and 1983 (87%, N = 277) and may have been able to "afford" the higher energetic costs of these long flights because prey was abundant. In 1984 jackrabbit numbers were low and eagles may have compensated for this scarcity by roosting closer to foraging areas; only 45% (N = 193) of the roost locations of marked eagles were in canyons that year.

Feeding sites and foraging area distances were longer for eagles using canyon instead of valley roosts. Eagles also roosted on the ground in the central portion of the valley during 1984. The lone juniper referred to earlier appeared to be incapable of holding the entire roosting population and 3 - 11 eagles were seen on the ground near the juniper at first and last light.

Earlier investigators determined the importance of roosts to wintering eagles in Rush Valley by comparing duration of use (Edwards

1969) or by numbers of eagles seen there (Joseph 1977). The results of these comparisons, however, differed markedly between studies and it is unknown if their dissimilarities are real or attributable to differences in data gathering technique (Table 13). In the present study, a more accurate importance value for each roost site incorporates both amount (relative use) and frequency (relative frequency) of use by radio-tagged eagles.

Importance values for roost areas located during the study were generally lower than those identified in previous investigations (Table 13). Red Pine was an exception, however, since it was considered more important than Black Rock (Edwards 1969). Ophir received a similar high ranking during earlier studies (Edwards 1969, Joseph 1977) and probably harbors more eagles than any other roost during population peaks in Rush Valley.

The importance of the Vernon roost, however, had been disputed in earlier studies. Edwards (1969) found it to be least important while Joseph (1977) identified it as most important. I suspect the census technique used by Edwards (1969) led him to underestimate the number of eagles using Vernon. He attempted to census all roosts in Rush Valley on a single evening and counts at some roosts must have been completed before counts at other roosts were begun. Eagles arrive at roosts for over an hour past sunset (Lish 1973, Sabine 1982) and if counts were conducted early in the evening at Vernon, then only a fraction of the eagles using that site would have been recorded. Another possibility is that Edwards' (1969) rankings document real shifts in roost use. More eagles were seen by Edwards (1969) at Black

Table 13. Comparison of roost importance rankings for studies on Bald Eagles in Rush Valley, UT.

	1982	1983	1984	Avg.	Joseph	Edwards
Vernon	3.5	3	1	2	1	3.5
Fairfield	-	-	-	-	3	3.5
Black Rock	3.5	6	3	5	4	1
Ophir	1	1	2	1	2	2
Gardison	7	2	6	6	-	-
Red Pine	2	4	4	3	-	-
Clover	6	5	5	4	-	-
7 Mile	6	6	-	7	-	-

Rock than at Ophir during both years of his study while relatively few eagles have been seen there since; no significant shifts in roost ranking were noted between 1977 (Joseph 1977) and this study or from 1982 to 1984 (Kruskal Wallis w = .813 and w = .838, respectively).

Functional Significance of Communal Roosting. A number of selective factors have been implicated in the evolution of communal roosting in birds. The major theories proposed are: 1) predation pressure (Wynne-Edwards 1929, Weller et al. 1955, Gadgil 1972, Hayward and Garton 1984), 2) limited availability of acceptable roosting habitat (Burns 1957, Edwards 1969, Balda et al. 1977, Barrows and Barrows 1978, Lyon and Caccamise 1981, Keister and Anthony 1983), 3)energetic considerations (Siegfried 1971, Tast and Rassi 1973, Gyllen et al. 1977, Kelty and Lustick 1977, Walsberg and King 1980, Fleming 1981, Itoh 1984, Stalmaster and Gessaman 1984), and 4) information transfer among roosting individuals (Siegfried 1971, Ward and Zahavi 1973, DeGroot 1980, Hansen et al. 1980, Loman and Tamm 1980, Knight and Knight 1983, Weatherhead 1983).

Predation pressure on nocturnal aggregations of bald eagles has not been reported and was not considered to be an important influence on the formation of roosts. The function of bald eagle communal roosts appears to be related to physical and energetic characteristics of roost sites and the possibility of information transfer there. Bald eagles may form communal roosts in response to a shortage of acceptable habitat (Swisher 1964, Robards and King 1966, Edwards 1969, Stalmaster 1981, Keister and Anthony 1983). Edwards (1969) believed that canyon roosts in Rush Valley were formed in response to limited availability of coniferous stands along sheltered exposures.

Five new canyon roosts were located at regular intervals around the periphery of the valley. Other canyons, similar to those being regularly used for roosting, have not had eagles reported in them. It appears, therefore, that acceptable coniferous habitat is not influencing bald eagle population size in Rush Valley. The scarcity of willow stands on the valley floor, however, may have limited their use by bald eagles.

Habitat selection in birds is strongly influenced by the amount of time birds have spent there (Gluck 1984) and roosts may have been selected because of their vegetative similarity to nest sites (Balda et al. 1977, Hayward and Garton 1984). Bald eagles commonly nest in conifers and initial roost selection in Rush Valley was probably at canyon sites because conifers are found only at these higher elevations. The 5 canyon roosts inventoried all opened to the north and eagles could have later moved to these stands because they offered the most protection from prevailing southwesterly winds.

Valley roosts were apparently selected because willow share structural similarities with cottonwoods (Populus deltoides) which were commonly used by wintering eagles elsewhere (Southern 1963, Lish and Lewis 1975, Steenhof 1976, Griffen 1978, Sabine 1982). Eagles also tend to use large trees to roost in because they offer the greatest visibility of surrounding terrain and favorable branching patterns for takeoff and landing.

Harmata (1984) believed that the most important influence on roost suitability was its isolation from disturbance factors. Canyon roosts were well insulated from disturbance during most of the winter. Ophir was the only canyon with a plowed road, and the steep slopes and deep snows of the canyon roosts made them inaccessible to humans through most of the winter. Valley roosts were located on private property where landowners protected the sites from disturbance. Edwards (1969) reported that eagles at valley roosts tolerate the routine activities of humans at homes nearby. In a few instances, roosting patterns of radio-tagged individuals showed strong preferences for one or two sites which would permit habituation to form. This does not appear to be the rule, however, as most marked eagles used a variety of roosting areas.

Energetic considerations associated with roost formation include migratory assemblages (Meinertzhagen 1956, Burns 1957, Braestrup 1963), microclimate (Tast and Rassi 1973, Yom-Tov et al. 1977, Barrows and Barrows 1978, Walsberg and King 1980, Stalmaster and Gessaman 1984), and roost proximity to foraging areas (Seibert 1951, Hurrell 1956, Klimstra and Ziccardi 1963, Bildstein 1979, Griffen et al. 1982, Craig and Craig 1984). Northward movements of marked eagles lacked the synchrony of birds which use roosts for migratory assemblages; this was not considered an important influence in the formation of communal behavior in bald eagles. Microclimate and proximity to feeding sites are probably the most important factors in roost selection.

Roosting has been proposed as a means to reduce thermal stress in corvids (Burns 1957, Tast and Rassi 1973, Balda et al. 1977, Fleming 1981, Stiehl 1981), icterids (Jumber 1956, Thompson and Coutlee 1963, Brenner 1965, Meanley 1965, Davis and Lussenhorp 1970, Francis 1976, Kelty and Lustick 1977, Yom-Tov et al. 1977, Lyon and Caccamise 1981, Heisterberg et al. 1984), ardeids (Siegfried 1971, Itoh 1984), galliformes (Klimstra and Ziccardi 1963, Mackey 1984, Stormer 1984) and passerines (Miller and Twining 1943, Knorr 1957, Frazer and Nolan 1959, King and Wales 1964, Ward and Zahavi 1973, MacMillan and Carpenter 1980, Walsberg and King 1980, Hendrick 1981, Gill and Dow 1985).

The importance of microclimate in the origin of roosting behavior is unknown and ranges from principal importance (Tast and Rassi 1973, Kelty and Lustick 1977, Barrows and Barrows 1978) to simply one of many contributing factors (Thompson and Coutlee 1963, Armstrong 1970, Gyllin et al. 1977, Walsberg and King 1980, Caccamise et al. 1983). It is readily apparent, however,that the use of topographic or vegetational features to insulate birds from adverse weather conditions is widespread across taxa.

Protection from high winds and reduction of radiative heat loss are the main thermoregulatory advantages of raptor roosts (Schnell 1969, Bildstein 1979, Hansen et al. 1980, Barrows 1981, Smith 1981, Bosakowski 1984, Craig and Craig 1984, Hayward and Garton 1984, Stalmaster and Gessaman 1984, Keister et al. 1985). Conifers can reduce ambient windspeeds by nearly 100% (Hansen et al. 1980, Stalmaster 1984) and lessen radiative heat loss because of their opaque cover (Moore 1945, Stalmaster and Gessaman 1984). Stands of evergreens are used for roosting by owls (Barrows and Barrows 1978, Barrows 1981; Smith 1981, Bosakowski 1984, Hayward and Garton 1984), rough-legged hawks (Schnell 1969), and bald eagles (Edwards 1969, Shea 1973, Hansen et al. 1980, Stalmaster and Gessaman 1984, Keister et al. 1985).

Behavioral adaptations to cold are more rapid than physiological ones (Brenner 1965). In wintering areas with fluctuating weather conditions, movement between roosting areas is one way to control energetic losses, and changes in roosting patterns are known to have been caused by unstable weather conditions (Bildstein 1979, Heisterberg et al. 1984).

I compared energetic costs of roost flights with thermoregulatory advantages of roost structure using formulas developed by Stalmaster (1984). There was no significant difference in roost flight distances between 1982 and 1983 so these years were pooled and results were compared against 1984. A mean flight speed of 41 km/hr (N =155) was substituted for the 45 km/hr reported by Stalmaster (1984). Overall mean energy cost of roost flights (13.0 kJ/km) was slightly higher than that in the Nooksack Valley, WA (11.9 kJ/km) (Stalmaster and Gessaman 1984) and was probably due to the difficulty in reaching canyon roosts. The average energy expenditure in roost flights during 1982-1983 was 172.5 kJ compared to 104.0 kJ per flight in 1984.

Distances from roosts to feeding areas were shortest in 1984 which could account for reduced energy costs of flights during this year. I maximized the probable disparity in flight costs between roost types by using a different flight mode for each. All flights to and from valley roosts were considered entirely active and those to canyons were considered 65% passive and 35% active. Mean flight speed to valley roosts and canyon roosts was 46.8 km/hr (N = 79) and 35.0 km/hr (N= 76), respectively. Flight costs to and from canyon sites averaged 135.0 kJ compared to 73.5 kJ of valley roosts. Shorter distances and higher flight speeds accounted for nearly a 50% reduction in energy expenditure at valley roosts. Once again, canyon roosts were located at higher elevations which required more time and energy to reach. Stalmaster (1984) reported that roosts farther than 3.9 km from feeding sites would incur a net energy loss to eagles roosting there. Valley roosts in central Utah were a mean distance of 5.3 km from feeding areas while canyon roostswere 13.6 km away.

The sheltered microclimate of canyon roosts conserves energy by protecting eagles from the wind and limiting radiative heat loss (Keister and Anthony 1983, Stalmaster1984). Radio-tagged eagles spent an average of 74% of their day at roosts. Under average weather conditions, 100.9 kJ/day were saved by selecting coniferous instead of deciduous habitat. Subtracting average flight costs to and from canyon roosts (2 x 135.2 kJ/flight) from average energy savings (100.9 kJ/day) a net energy loss of 169.5 kJ/day was obtained. Flight costs to and from valley roosts resulted in an average net energy loss of 147.0 kJ/day.

Under average weather conditions, there appears to be a slight (8.6%) energetic advantage in using valley roosts. Adverse weather conditions, particularly high winds, presumably dissipate the energetic savings of valley roosts and eagles shift to the more protected canyon sites. Conditions must be exceptionally severe, however, to cause this shift because eagles used valley roosts most in 1984 in spite of the fact that this winter was the most severe of the study period.

There appears to have been an energetic trade-off involved in roost selection. Canyon roosts required more energy expenditure to reach than valley roosts because of their greater distance from foraging areas. The sheltered microclimate of coniferous trees along canyon slopes, however, conserved energy for roosting eagles. More eagles used canyon roosts during periods of inclement weather (e.g. low temperatures, high winds); valley roosts were used most often during periods of milder weather.

Eagles also reduced energetic costs of flight to feeding areas during periods of low prey numbers by using nontraditional roosts. Three roosts, 2 in valleys and 1 in a canyon, were used by marked birds only during 1984. Some eagles also moved from roosting in the canyon at Ophir to a group of cottonwoods along Ophir Creek on the valley floor. The site was 5 km closer to feeding areas and was within 1 km of State Highway 73. The use of this and other nontraditional roosts during periods of low prey availability suggests that energetic costs incurred between roosting and foraging areas principally influenced roost selection in Rush Valley; microclimate and disturbance factors were secondary.

The information center hypothesis (ICH) proposed by Ward and Zahavi (1973) has been widely used to explain the evolution of bird assemblages. The hypothesis proposes that information on the location or quality of food takes place between neighbors at roosting or breeding sites. The theory has received much support (Krebs 1978, DeGroot 1980, Hansen et al. 1980, Brown 1986) but is nearly devoid of direct empirical support (Zahavi 1971, Anderson and Gotmark 1980, Anderson et al. 1981, Bayer 1982, Post 1982).

Jackrabbit carcasses provided by hunters appeared to meet the conditions of a food source under which ICH could operate. The ephemeral, unpredictable, and non-defensible nature of carrion enhanced the likelihood that information transfer would occur at bald eagle communal roosts. This was not supported by my results.

For roosts to serve as information centers, successful individuals must be recognized by unsuccessful ones and then followed to their food sources. I attempted to identify possible behavioral cues given by successful bald eagles to other members of the roost.

Knight and Knight (1983) reported that eagles followed each other more when departing roosts than when entering, and following behavior was more prevalent at roosts after storms. They believe that these behaviors are consistent with ICH and support the possibility of it operating within communal roosts of bald eagles. No tendency to follow other eagles to or from roosts was noted in the present study. Most eagles left roosts over a shorter period of time compared to those returning, but eagles dispersed in a variety of directions and over a range of distances during morning departures.

"Following" is a difficult behavior to define which, even if present, may have nothing to do with information transfer at roosts.

Synchronous departures could be caused by climatic conditions such as light intensity (Erwin and Ogden 1980) or tide (Krebs 1974, Bayer 1981). Birds leaving in groups may disperse before reaching foraging areas (Hamilton and Gilbert 1969, Siegfried 1971, Tast and Rassi 1973, Hafner et al. 1982) or may even be solitary territorial feeders (Meanley 1965, Councilman 1974, Post 1982). Vultures leave roosts separately but become associated at carcasses (Stewart 1979). No evidence of following has been found in pied wagtails (Motacilla alba) (Fleming 1981), black-headed gulls (Larus ridibundus) (Anderson et al. 1981), or skua (Catharacta skua) (Anderson and Gotmark 1980) colonies.

Information transfer is unlikely at bald eagle roosts because food sources were not available long enough to permit transfer of location information between individuals. Jackrabbit is the principal prey type and each carcass had an average of 2.8 eagles (N = 88) present. It is doubtful that any food remained after eagles left most rabbit carcasses. Marked birds waited a mean duration of 4.6 hrs after feeding before returning to roost. Few eagles were present at roosts during the day and eagles rarely left a roost after returning until the following day.

This low rate of return seems justified when the energetic costs of flying to and from roosts are considered. Jackrabbit supplies 6.8 kcal of metabolizable energy to feeding eagles (Stalmaster and Gessaman 1982). The amount of energy expended by an eagle flying to a roost, waiting, and following another eagle that it believes was successful seems to be greater than could be gained at most carcasses.

Larger carrion, like sheep, would be present for a long enough period of time to permit information exchange to occur at roosts. Radio-tagged individuals returned to within 2 km of the previous day's feeding site 63% (N = 19) of the time but only 2 of these were sheep. This high rate of return may be misleading because most marked eagles habitually used small diurnal areas and returned to them daily whether they had fed there or not.

Two behavioral cues could have been transmitted at roosts by successfully feeding eagles. Roost departures of birds on days they fed were earlier than average and were probably initiated by hunger. They also returned to roost later than the mean after feeding. No differences were noted in flight speeds of feeding eagles to or from roosts compared to other birds. Successful individuals probably were easily recognized by other eagles at roost sites because of their bulging crop. Since successful birds arrived at roosts late, eagles already present at valley roosts may have ascertained the general direction of a food source by monitoring flight paths of late arrivals. All eagles arriving late at roosts had not all fed, however, and distinctions in the flight behavior of successful and unsuccessful eagles would have to have been made by roost members. Following successful individuals the next morning remains a possibility, but the habitual nature of diurnal habitat use appears to make following unnecessary. Instead, eagles probably increased their foraging efficiency by becoming familiar with small areas of high prey density and regularly returning to them.

Migration

Marked eagles from central Utah followed a northward migration corridor into Alberta, Northwest Territories, and western Saskatchewan. Movement usually began during early March with eagles leaving individually, probably in response to changes in photoperiod (Brown and Amadon 1968). Bald eagles apparently migrate alone (Harmata 1984) and a variety of routes were taken to summering areas.

During March 1982 and 1983, 3 radio-tagged eagles were located near Willard Bay, UT. Young (1983) also reported eagles from Rush Valley stopping at this area during spring migration. Spring fish kills are common near Willard Bay and bald eagles feed on these and injured waterfowl (Swisher 1964, Badame 1981). Radio-tagged individuals were known to remain in this area for 2 to 20 days, supporting the position that wintering populations during spring are a mixture of transients and residents (Young 1983).

Another stopover area along the Yellowstone River, MT, was used by 2 marked eagles in 1983. Canada geese also winter here (Hinz 1974) and could provide a reliable food source. Swenson (1983) counted over 200 eagles along the Yellowstone River during late March, and Harmata (1984) found 2 of his marked eagles from southern Colorado in this same area. Bald eagles probably converged on this section of the Yellowstone River from a variety wintering areas.

Eagles arrived at their summering areas by early April. This is consistent with other studies (Young 1983, Harmata 1984) and local observations (Allen and Ealey 1979). There was a strong association between wintering and summering grounds. Nearly all the bald eagles from central Utah were found near the Mackenzie River watershed (McClelland, pers.comm.). The impact of management decisions at particular wintering areas, therefore, could have profound implications for relatively localized bald eagle breeding populations.

Management Recommendations

Diurnal Habitat. Areas of consistent use by wintering bald eagles have been identified in Rush Valley and management efforts should be directed at maintaining and enhancing these sites.

In Rush Valley, wintering bald eagles appear to be principally dependent on mammalian carrion for their food. The main prey type appeared to be hunter killed black-tailed jackrabbit. Sheep fatalities during winter grazing in the valley supplement the eagles' diet. Maintenance of the current wintering bald eagle population depends upon distinguishing between appropriate human activity and human disturbance in eagle foraging areas.

Management guidelines can best address this issue by determining the nature and duration of activity proposed in these areas. Any activity which would reduce the availability of prey to wintering eagles on the valley floor should be prohibited. These include land use practices which would adversely affect the vegetation or topography of eagle foraging areas (e.g. roadbuilding, revegetation, mining, grazing). In areas of high eagle use, management practices should ensure the reliable availabilty of jackrabbits and perches, typically fenceposts and junipers.

The use of artificial perch structures may enhance the use of foraging areas by bald eagles. Significantly less time was spent by eagles perched on the ground than those perched on fenceposts or deciduous trees. Eagles perched on the ground are more sensitive to human disturbance than those perched in trees (Stalmaster and Newman 1979, Harmata 1984) and eagles in Rush Valley may have compensated for this by selecting elevated areas of ground. Harmata (1984) reports that bald eagles used artificial perch structures near areas of assumed high prey densities in the San Luis Valley, Colorado. Placement of one of these structures in a high eagle use area could then be monitored for its effectiveness in attracting wintering bald eagles. A quicker and less expensive option would be the placement of 4 x 4 fenceposts bound to a crosstie at appropriate sites within eagle foraging areas.

Medium use areas should receive secondary consideration, as these sites provided diurnal perch sites and periodically offered food sources. Lowest management priorties should be given to low eagle use areas, as many of these sites presently lack a suitable prey base and others are subject to high levels of human disturbance.

Human access to areas of high and medium use by eagles should be limited to activities of comparatively short duration (Grier et al. 1983) from 15 November through 15 April. Hunting is obviously an important and acceptable activity in these areas, but there should be a strong educational emphasis on prevention of shooting at the eagles themselves. Prolonged or extensive activities (e.g., camping, snowmobiling, motorcycling), however, should be prohibited in areas of high eagle use. Sheep grazing should also not be allowed to adversely affect jackrabbit forage in areas of high eagle use.

Cooperative efforts by federal and private ranchers should promote land use practices which enhance habitat for wintering bald eagles in Rush Valley. Public information and education is a powerful management tool in this endeavor (Harmata 1984). The movement of dead livestock away from roadways would be one way ranchers could enhance the availability of food supplies for wintering eagles.

<u>Roost Sites</u>. Canyon roosts were located on public lands and were predominantly inacessible during winter, and human activity near these sites during winter was considered negligible. Valley roosts, however, were located on private lands, and management efforts should be directed at protecting these sites from excessive human disturbance. The roosts at Vernon are particularly vulnerable to disturbance due to their easy access. Management efforts should be particularly directed at minimizing human disturbance at this site. Birdwatchers should remain in their cars near this roost and closer activity should be restricted to ranching activities to which the eagles have become accustomed.

Roost trees should be protected at both valley and canyon sites. Valley roosts are composed of few (10-15) trees and young trees in these areas should be protected to ensure natural regeneration. Canyon roosts are susceptible to fire sparked by lightning during the summer months. Small isolated fires in canyon forests help maintain spatial heterogeneity, but large continuous fires could destroy all trees within a canyon roost. The size of fires near canyon roosts therefore should be restricted to small controllable fires. Timber harvesting near canyon roosts should employ selective cutting techniques, and stands should be maintained to provide maximum numbers of potential roost trees.

Lastly, cliff faces and ridges bordering canyon roosts should be protected from alteration. Mining or other activities which permanently alter the topography in or near roost sites should be prohibited.

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ASPECTS OF BALD EAGLE WINTER BEHAVIOR IN RUSH VALLEY, UTAH: A TELEMENTRY STUDY

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ABSTRACT

The diurnal behavior and nocturnal roosting patterns of 28 bald eagles outfitted with tail-mounted radios were investigated in Rush Valley, Utah between January and March 1982-1984. Casting analysis and feeding observations indicated the principal food source was jackrabbit carrion. Jackrabbit availability declined from 1982 to 1984 and eagles responded by; 1) roosting closer to feeding sites, 2) shifting from canyon to valley roosts, 3) arriving later at and departing earlier from roosts, 4) decreasing diurnal activity, and 5) decreasing residence time. Foraging efficiency appeared to be maximized by experienced eagles using familiar feeding areas and by naive birds monitoring their activity. There appeared to be a slight (8.6%) energetic advantage to roosting at valley sites because of their proximity to feeding areas. This saving was presumably dissipated under adverse weather conditions when eagles selected the sheltered microclimate of canyon slopes. Twelve eagles were tracked during spring migration and all followed northward routes.

COMMITTEE APPROVAL