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ROUGH-LEGGED HAWK WINTER ECOLOGY IN SOUTHEASTERN IDAHO

by

James Ward Watson

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

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

March 1984

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James Ward Watson

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ABSTRACT

Ecology of the American rough-legged hawk (*Buteo lagopus*) was investigated during winters 1981-82 and 1982-83. Research was conducted in sagebrush-dominated habitat on the Idaho National Engineering Laboratory Site in southeastern Idaho. Spatial distribution of the hawk population was influenced by vegetation canopy, which reduced foraging efficiencies of monitored hawks. Temporal distribution was influenced by rabbit carrion availability and snow cover over 10 cm, which accounted for 65% of the variability in hawk numbers. Hawks consumed carrion and voles in different proportions on sagebrush habitat and adjacent farmland. Radio-tagged hawks exhibited two patterns of range use. Three hawks maintained a pattern of drift between small, non-overlapping ranges. Four hawks occupied well-defined ranges between 70.2 and 541.2 km^2 which encompassed smaller, overlapping weekly ranges. Weekly ranges were characterized by size reduction in mid-winter due to increased perching activities which conserved energy. Monitored hawks also shifted to grass-dominated areas or highways in the period of severe weather. Transmission lines were important components of ranges. Utility poles influenced range shape and size and were used extensively as hunting and roosting substrates. Hawks exhibited little range defense but defended perches and prey near activity centers. Other aspects of social behavior, hunting success, roosting behavior and food habits were reported. Premigratory movements up to 120 km from ranges were exhibited by three hawks. Movements of two hawks averaged 120 km per day for two days of migration. Winter range fidelity was displayed by at least one individual. The presence of marked hawks resighted in states surrounding Idaho reflected the opportunistic nature of this species. Theoretical considerations suggested this population originates in western Canada.

INTRODUCTION

Identification and protection of important habitats are essential to maintain viable populations of raptors (Snyder and Snyder 1975, Olendorff et al. 1980). Research during the past decade has provided a better understanding of the relationships between birds of prey and their habitat and resulted in land-use planning to include the preservation of habitat for raptors. However, most studies have investigated aspects of breeding biology and there remains a lack of information concerning habitat use and factors limiting winter populations (Newton 1979, Wilkinson and Debban 1980, Fleming 1981).

The American rough-legged hawk (*Buteo lagopus*) is the most numerous raptor, both as a migrant and winter resident, in many areas of the western United States (Woffinden and Murphy 1977, Thurow et al. 1980, Bauer 1982). However, information on the winter ecology of this species is limited and generally restricted to studies in agricultural areas. Weller (1964) and Schnell (1967a, 1967b, 1968, 1969) investigated such aspects as population fluctuations, spatial distribution, food habits, social behavior and habitat utilization of rough-legged hawks in the midwest. A comprehensive study of raptor predation in Michigan (Craighead and Craighead 1956) and a comparative

study of wintering buteos in Sweden (Sylvén 1978) have been the only attempts to describe, from limited observational data, the movements and ranges of rough-legged hawks. However, virtually nothing is known about their origins or dispersal from and fidelity to winter ranges. More recent studies have focused on energetics and predatory and social behavior of this species (Bildstein 1978, Smith 1979, Griffen 1983).

The Idaho National Engineering Laboratory (INEL) Site, located on western rangeland in southeastern Idaho, is an important wintering area for rough-legged hawks and other raptors (Craig 1978). Although rough-legged hawk winter distribution and abundance have been circumstantially linked with prey density (Craighead and Craighead 1956, Baker and Brooks 1981) other factors may influence bird numbers (Newton 1979). A better understanding of these factors and their influence on rough-legged hawk distribution on the INEL Site is important since this species could consume contaminated prey near nuclear facilities (Halford 1983) and become a mode of radionuclide transport.

This study is believed to be the first attempt to gather data on the winter ecology of the rough-legged hawk by monitoring radio-tagged and wing-marked individuals. Objectives of this research were to determine rough-legged hawk 1) movements, ranges and

behavior patterns; 2) food habits; 3) spatial and temporal distributions and their relationship to perch availability, vegetation canopy, prey abundance, and weather factors; and 4) to assess the population status of all raptors on the INEL Site during winter 1982-83. Full-time field research and data collection were conducted January through April 1982 and October 1982 through April 1983.

STUDY AREA

Location and Physiography

The INEL Site is situated along the western edge of the upper Snake River Plain at the base of the Lemhi and Lost River Mountains (Figure 1). The Site encompasses 2315 square kilometers (km^2) of rolling sagebrush desert in portions of Clark, Jefferson, Bonneville, Bingham and Butte Counties. Prominent landmarks include Middle and East Butte which rise 426 and 428 meters (m) above the average elevation of 1524 m. Big Southern Butte which lies adjacent to the Site, rises to an elevation of 785 m above it's surroundings.

The entire study area is a structural depression resulting from the interbedding of volcanic rock and lake and alluvial deposits (Atwood 1970). Past lava flows from the three buttes resulted in craters and cones which lay exposed in much of the southern portion of the Site. Except for basalt exposures, soils are primarily alluvial, lacustrine, or windblown sediments (Harniss and West 1973). The nature of these soil types prevents largescale erosion of the landscape.

Three major stream channels drain into the Site. Birch Creek and the Little Lost River flow intermittently

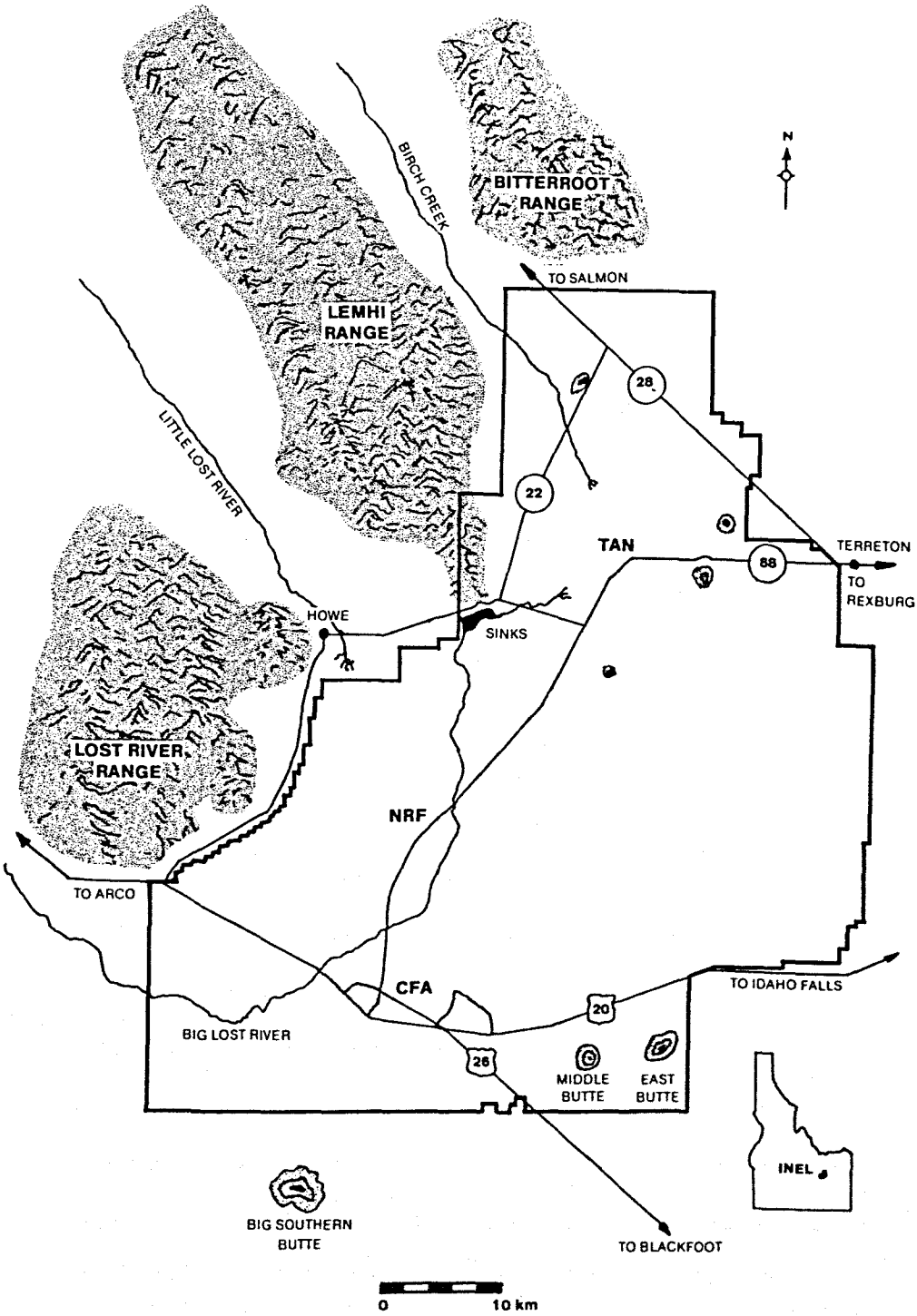

Figure 1. Location of the INEL Site in southeastern Idaho in relation to topographic features and landmarks.

from the northwest after periods of heavy rainfall or snowmelt. The Big Lost River flows 50 km into the Site from the southwest and drains into the Sinks at the foot of the Lemhi Mountains. In most years flow is reduced or eliminated in late summer by upstream water withdrawal for irrigation.

Climate and Weather

Hot summers, cold winters and low precipitation characterize the climate of the INEL Site. The Beaverhead and Centennial Mountains north of this area tend to prevent extremely low temperatures, reduce precipitation and channel the winds in this area (Atwood 1970). Although daytime winds are predominately from the southwest, wind direction varies across the Site. Due to the effects of the surrounding topography, only 30% of the daytime winds are southwesterly in the north compared to 50% in the south-central portion of the Site (Yanskey 1966). Nightime winds are predominately from the northeast.

Two major types of low fronts occur during the winter in the upper Snake River Plain which alter surface wind direction (National Weather Service, Pocatello, ID). Arctic air moving through Canada primarily in late fall/early winter results in low temperatures, low precipitation and winds from the north-northeast.

Southerly flows from Utah primarily in late winter/early spring bring warmer temperatures, heavier precipitation and southwesterly surface winds.

Mean annual temperature at the Central Facilities Area (CFA) is 5.8 Celsius (C), ranging between 3.7 and 6.9 C. January is typically the coolest month, July the warmest. Annual extremes in precipitation are 11.4 and 36.6 centimeters (cm) with consistent peaks in mid-winter due to snow and in mid-spring due to rain.

Average daily temperature during this study from January through April 1982 was 2.6 C or 0.7 C below normal for this period. Precipitation averaged 1.6 cm or 0.4 cm below normal. Temperature between October and April 1982-83 averaged 1.7 C or 0.7 C above normal and precipitation for this period averaged 2.2 cm or 0.4 cm above normal. Average daily minimum temperatures and snow depths for the second winter, during the period of most intense field research, are plotted in Figure 2.

Vegetation

Vegetation on the INEL Site is characteristic of the northern desert shrub biome and is predominated by big sagebrush (*Artemisia tridentata*) (Figure 3). Other prevalent shrubs include rubber rabbitbrush (*Chrysothamnus viscidiflorus*), saltbush (*Atriplex nuttali*), winterfat (*Ceratoides lanata*), dwarf sagebrush (*Artemisia arbuscula*)

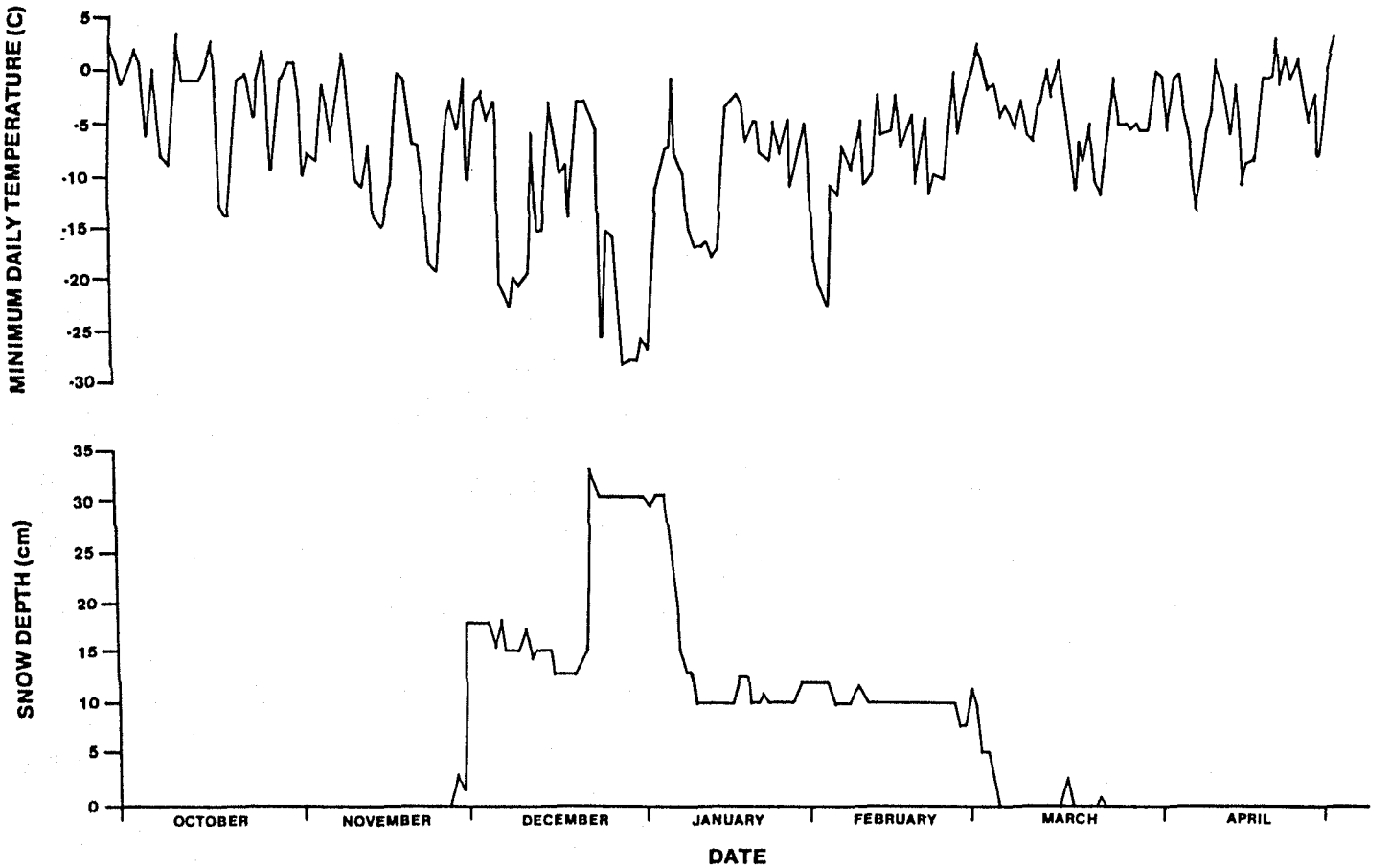

Figure 2. Minimum daily temperatures and snow depths on the INEL Site during winter 1982-83.

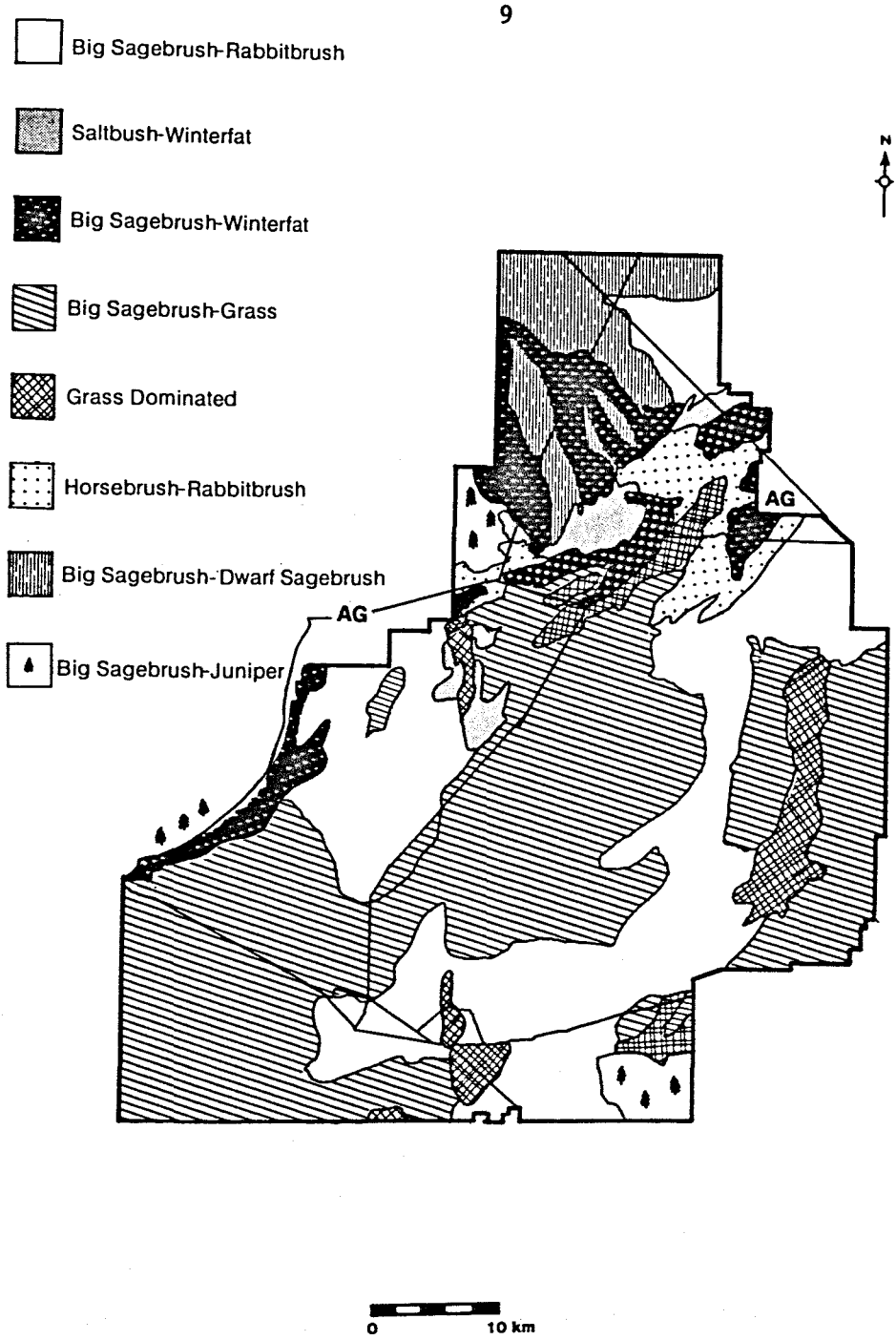

Figure 3. Dominant vegetative cover types on the INEL Site. Modified from McBride (1968).

and horsebrush (Tetradymia canescens). Bluebunch wheatgrass (Agropyron spicatum) and thickspiked wheatgrass (Agropyron dasystachyum) are major understory grasses.

Native vegetation is bordered by irrigated farmland near Howe and Terreton, Idaho, in the central portion of the Site. Crops are primarily alfalfa (Medicago sativa) grown in rotation with common barley (Hordeum vulgare).

Two tree species provide natural perch sites throughout the study area. Utah juniper (Juniperus osteosperma) is found on mountain foothills in association with sagebrush-grass vegetation and cottonwood trees (Populus deltoides) occur sporadically along the banks of the Big Lost River.

Site Use and Impacts

The INEL Site (formerly the National Reactor Testing Station) was established in 1949 primarily for the testing of nuclear reactors. The large land area required for isolation of the different research projects allowed the Site to be designated a National Environmental Research Park in 1975.

Since public access to the Site is limited to areas removed from test facilities, only raptors in remote areas are vulnerable to shooting. Other direct human impacts include vehicle collision and electrocution on power poles which serve as elevated perches between test facilities.

Major avian and mammalian species have been catalogued on the Site and are listed elsewhere (Harniss and West 1973, Reynolds 1978, Craig 1979). Ongoing monitoring of mammalian populations during this study indicated that black-tailed jack rabbits (*Lepus californicus*) were at peak abundance (J. Grant pers. comm.), while montane voles (*Microtus montanus*) were at low levels throughout the Site (B. Keller pers. comm.).

METHODS AND MATERIALS

Trapping Procedures

Rough-legged hawks were trapped and fitted with transmitters and/or wing markers to monitor their movements and activity. Hawks were trapped with noose carpets (Wegner 1981) wired around black-tailed jack rabbit and mountain cottontail (Sylvilagus nuttali) carcasses. Baits were dropped from a moving vehicle or placed on the ground near perched hawks. Captured birds were aged, sexed (Cade 1955, Hamerstrom and Weaver 1968), weighed, fitted with coded orange-vinyl patagial markers, and banded with USFWS lock-tight leg bands. Wing chord, culmen length and mid-tarsus width were recorded. Posters requesting information on marked hawks were distributed to government agencies in surrounding states and Canada to facilitate data collection of resighted hawks.

Radio-Telemetry

AVM SB2 transmitters with whip antennas were attached to the deck feathers of hawks similar to the technique described by Dunstan (1973). Radio locations were made with a portable 64-channel Cedar Creek receiver and 3-element yagi antenna. Several flights in fixed-wing

aircraft using a dual antenna system (Gilmer et al. 1981) were taken to locate lost and dispersing hawks.

Attempts to take compass bearings on all radioed hawks were made at least once a day from major buttes on the Site. Triangulation error from stationary transmitters of known location was ±0.43 km at an extreme distance of 14.5 km. However, 78% of all radio locations were verified visually. Radio locations with erratic pulses which indicated bird movement between locations were not recorded.

Activities of accessible radioed hawks were monitored daily. Aspects of social interaction, hunting success and roost behavior were quantified. Time devoted to perching and flight activities was recorded and activities were classified by the following definitions:

Perch-Hunt--Active hunting from a stationary perch. Included any perching activity where the hawk was not sleeping, preening or feeding.

Preen--Adjustment of feathers or wing-markers. Occasionally involved oiling feathers.

Feed--Consumption of fresh prey or carrion.

Prey Pursuit--Flight pursuit of prey from a stationary perch or flight directly to carrion for the purpose of feeding. Included hovering or flying into the wind to maintain a stationary position while hunting.

Directional Flight--Powered flight travel between perches, not involving pursuit of prey.

Soar--Prolonged non-powered flight initiated by kettling (rising in a circular pattern) up to several hundred meters above ground.

All radio and visual locations were plotted and analyzed by a Honeywell CP-6 computer through the Telday program package with range estimations based on the minimum area method (Mohr 1947). Hawk ranges were delineated based on the definition of Craighead and Craighead (1956) as limited areas of land occupied during a given period. Seasonal standard diameters encompassing 68.3% of the hawks' activity within a range were calculated by computer according to the following formula given by Harrison (1958): D^2/N where D is twice the distance of the geographic activity center or focus of the standard diameter (Hayne 1949), and N is the total number of relocations between specified dates.

Food Habits

Castings were collected on the Site and in agricultural land near Howe following both study periods. Only castings from known rough-legged hawk roost and perch sites were collected. Analysis was conducted by the technique of Errington (1932), with identification of mammal skull and jaw fragments from Glass (1973). Hair

analysis was conducted with the aid of Moore et al. (1974) to offset the under-representation of small mammal remains in pellets because of differential digestion of large and small mammal bones (Glading et al. 1943).

Prey weights for calculating prey biomass were taken from Steenhof (1983). Prey items assumed to be carrion included black-tailed jack rabbits, unidentified leporids, sage grouse (*Centrocercus urophasianus*), and pronghorn antelope (*Antilocapra americana*). These were assigned the weight value of 115 grams (g) based on the assumption that hawks consumed their full average daily consumption when feeding on carrion. This value was derived by taking the product of the average feeding rate (10.7% of the body weight) of the similar sized red-tailed hawk (*Buteo jamaicensis*) from Craighead and Craighead (1956), and the mean weight of rough-legged hawks from this study (1076.7 g).

Raptor Survey

A roadside raptor survey was conducted between 11 November 1982 and 20 March 1983 to assess the relative abundance of all raptors on the INEL Site. The 187 km vehicle route established by Craig (1978) was divided into nine sections (Figure 4) based on broad habitat differences (Table 1). Surveys were conducted approximately weekly on calm, dry days but were

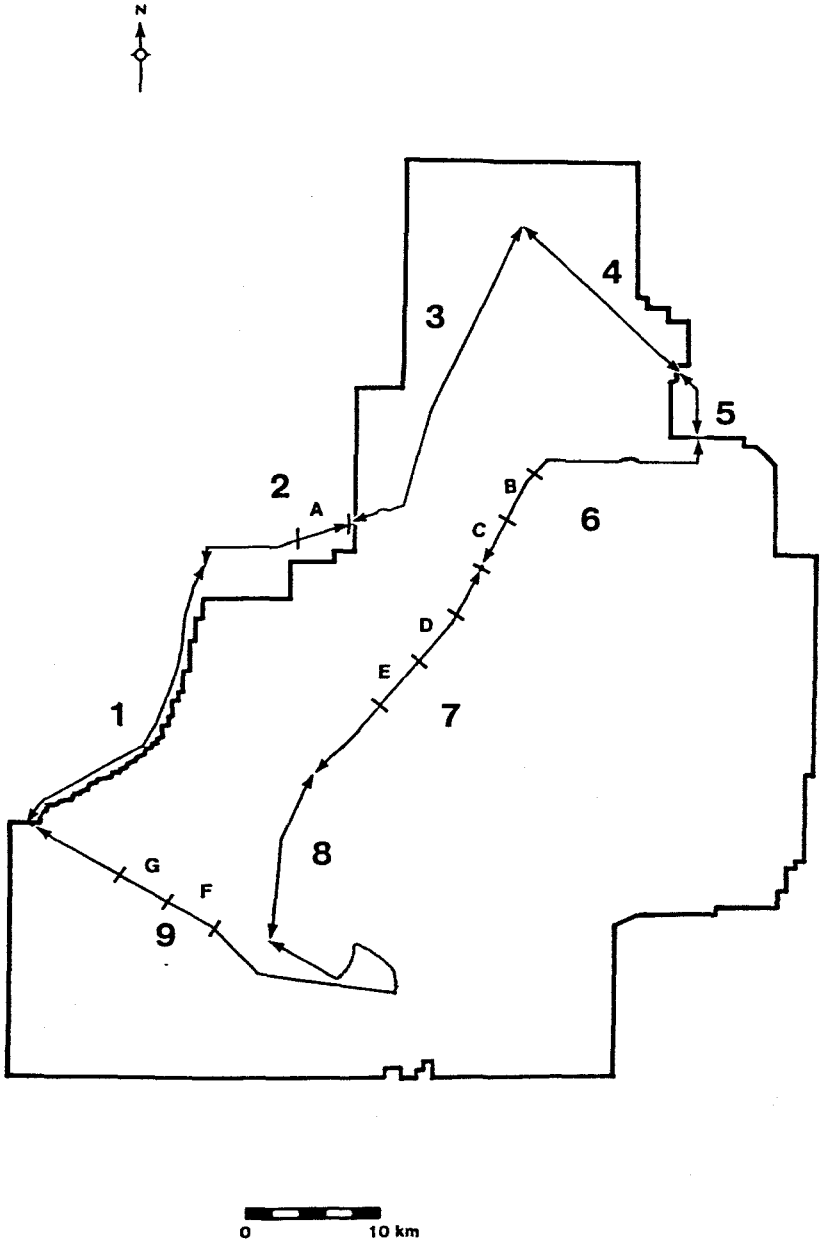

Figure 4. Raptor survey route on the INEL Site. Numbers identify survey sections and letters identify study areas where rodent abundance and vegetation canopy were estimated.

Table 1. Major characteristics of the raptor survey route on the INEL Site.

Section	Length (km)	Description
1	24.4	Dominated by sagebrush and winterfat with scattered junipers along foothills. Power line extending section length at distances generally greater than 0.2 km from highway.
2	11.6	Agricultural land. Power line extending section length adjacent to highway. Numerous elevated perches including utility poles, pivot wheels, sprinkler heads and haystacks in surrounding habitat.
3	25.6	Dominated by sagebrush-grass with smaller areas of horsebrush, rabbitbrush, and juniper. Power line extending most of section length generally at distances greater than 1 km from highway.
4	21.4	Dominated by sagebrush-rabbitbrush with smaller areas of horsebrush, saltbush and winterfat. No utility poles, scattered signs.
5	5.1	Agricultural land. Elevated perches primarily fence posts with few scattered utility poles.
6	21.3	Interspersed sagebrush-grass, horsebrush-rabbitbrush and ricegrass-rabbitbrush stands. Two major power lines extending about half of section length, one adjacent to highway, the other removed by 0.2 km. Numerous utility poles scattered around Site buildings.
7	18.6	Homogeneous stand of sagebrush-thickspiked wheatgrass. Power lines extending section length adjacent to and at least 0.2 km from highway.
8	14.2	Dominated by sagebrush-grass. Power lines extending section length adjacent to and at least 0.2 km from highway. Numerous power lines around Site buildings.
9	44.8	Dominated by sagebrush-grass. Power line extending most of survey length at least 0.2 km from highway. Numerous power lines extending from and around Site buildings.

occasionally delayed due to inclement weather. Observations began at 0800 Mountain Standard time and ended about 1300 hours (h).

To reduce visibility bias due to differences in habitat structure, one of two observers recorded raptors on elevated perches exclusively, while the other recorded ground-perched birds. Survey direction was alternated each census and the survey driven at 45 kilometers per hour (KPH) to reduce observation bias due to changes in the diel behavior of raptors. Although this speed is faster than most reported raptor surveys (Fuller and Mosher 1981) and may decrease the chance of sighting raptors, it also decreases the chance of resighting the same birds (Craig 1978).

Species, location, activity and perch type were recorded for all observed raptors. Perch heights were estimated with a Brunton Compass clinometer. Age, sex and color phase data were collected for rough-legged hawks. Momentary stops were made to identify unknown raptors with a 15-60x spotting scope.

Environmental parameters were quantified to assess their relationship to rough-legged hawk distribution on the survey route. Road-killed rabbits were tallied within each section for each survey. Elevated perch sites including utility poles, trees, fenceposts, signs, haystacks, sprinkler heads and pivot wheels were also

counted within each section. Weather information was supplied by the National Oceanographic and Atmospheric Administration (Central Facilities Area, INEL Site).

Relative rodent abundance and vegetation canopy were estimated in sections 2, 6, 7 and 9 in September 1982. These sections were selectively chosen on the basis of variable rough-legged hawk numbers among them from previous surveys (Craig 1978, Craig et al. 1983). Two 4 km x 0.8 km (0.25 mile each side of road) study areas were chosen within sections 6, 7 and 9 and one in section 2 (Figure 4). Four single line transects were established 1 km apart and perpendicular to the road in study areas A through D for adequate sampling (Johnson 1977). Two museum special snap traps baited with peanut butter and rolled oats were set at each of 26 stations per transect. Traps in study areas A, B and C were set in each habitat type according to the proportion of that type to the total study area. Habitat types in study area A included fencerow, plowed field and matted alfalfa, while B and C included sagebrush-winterfat, sagebrush-grass and grass-dominated habitat types. Rodent abundance was indexed by dividing the number of rodents caught by the product of the number of traps and the number of nights traps were set.

Vegetation canopy was measured at each trapping station by two techniques. Percentages of shrub, forb and

grass cover were estimated by the technique described by Daubenmire (1959). Percent incident light on the ground was also measured by taking the average of four light readings from the corners of the Daubenmire quadrat with a General Electric Triple Range Light Meter, and dividing by the average of four light readings above the canopy at each station.

Data were analyzed primarily by the chi-square test of equal proportions, Spearman's rank correlation and two-tailed t test. Other statistical tests are described with results. All tests were conducted at the 0.05 level of significance.

RESULTS

Movements, Ranges and Behavior

Fall Migration

Rough-legged hawks in fall migration were first observed north of the Naval Reactor Facility (NRF) on 6 October 1982. Peak numbers of migrating hawks followed the passage of a westerly cold front on 8 October and a northerly front on 19 October when 8 and 12 birds were observed, respectively. Subsequent declines in migrating hawks occurred the days following these fronts. Flight direction of all migrating hawks was south to southeast across the central portion of the Site indicating probable passage from the Little Lost River Valley.

By 28 October no hawks were seen in migration and two wing-marked birds were observed in the same area over successive days. Thus winter resident hawks became established as early as late October.

Seasonal Ranges

Twenty-two rough-legged hawks were trapped and relocated 2,347 times during combined study periods. Data relating to all trapped and fresh road-killed hawks are given in the appendix, Tables 14 and 15.

Nine adult hawks were radioed and monitored throughout winter 1982-83. Occupation of the winter range followed one of two patterns. Three hawks maintained a pattern of drift throughout winter with extensive extra-range movements between non-overlapping ranges. The remaining birds occupied well defined ranges encompassing smaller, overlapping weekly ranges.

Hawks 15, 20 and 21 exhibited the first range use pattern (Figure 5). Female 15 occupied a 10.9 km^2 range for 5 days in mid-November and moved 72.5 km northeast near Hamer, Idaho to an area dominated by mixed sagebrush and agriculture. She remained in this vicinity until lost on 2 February. Male 20 remained on the Site following radio-tagging from 1 January until 3 February. Movements up to 24.9 km from the 72.6 km^2 range were followed by a return to this range for 15 days in late February. On 15 March hawk 20 was located 63.8 km to the northeast near Dubois, Idaho, in an alfalfa field and remained in this area until migration on 14 April. Female 21 was trapped on the Site 22 December near the Big Lost River Sinks and moved 33.0 km south to the CFA by 29 December. Occupation of the 36.1 km^2 range ended when her signal was lost 3 February.

Signal loss of hawks 15 and 21 and the extra-range movement of hawk 20 coincided with the passage of a major southerly front beginning 27 January. Extensive aerial

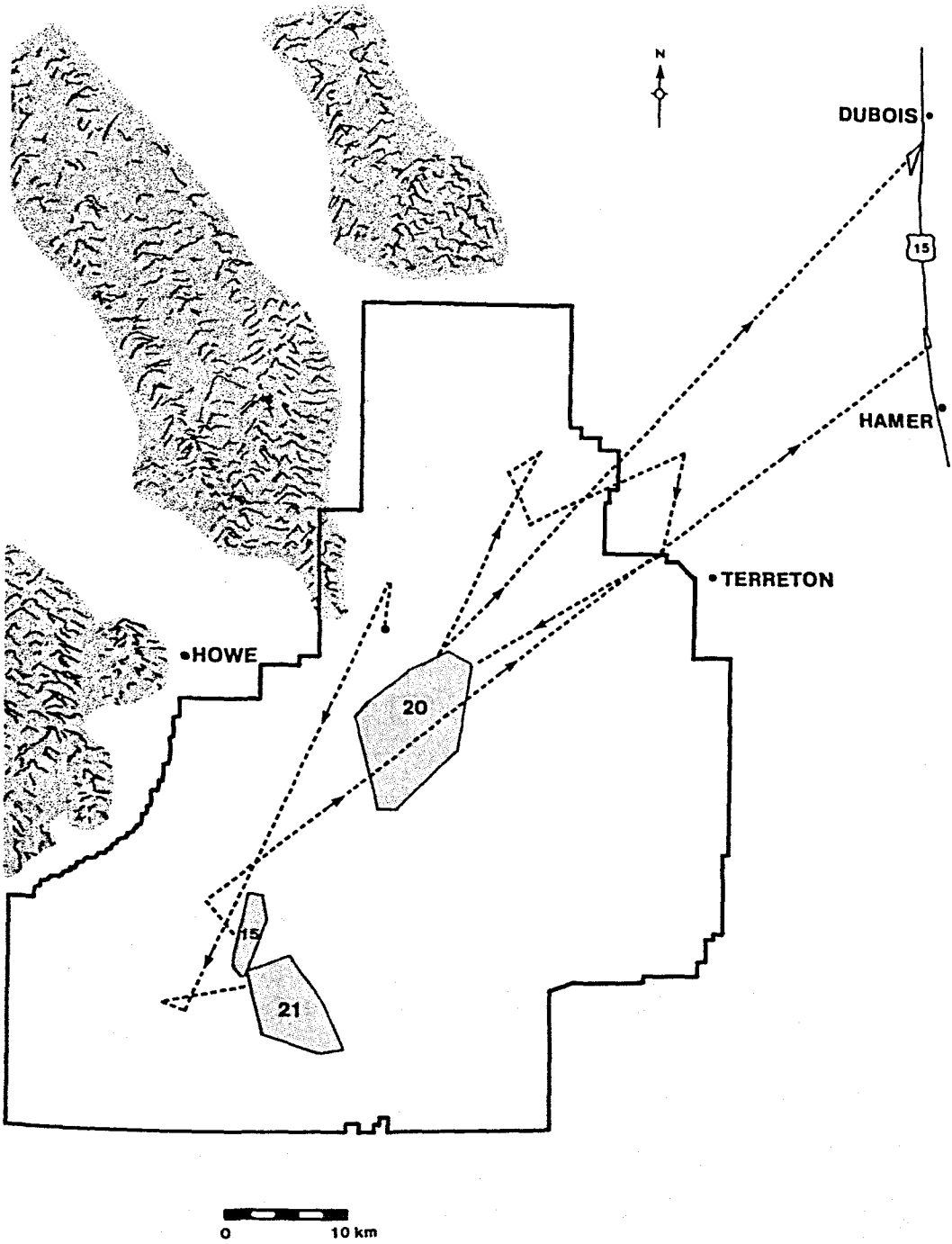

Figure 5. Range occupation and drift of hawks 15, 20 and 21 in southeastern Idaho during winter 1982-83.

surveys in the upper Snake River Plain during that period failed to locate the lost birds. Since both transmitters were functioning well at last locations, hawks were believed to have moved from this area. Range data for these three hawks are summarized in Table 2.

Table 2. Data relating to ranges occupied by hawks 15, 20 and 21 in southeastern Idaho.

Hawk	Inclusive Dates of Observation	No. of Days	n[1]	Area (km^2)	Standard Diameter (km)
15	11/12/82-11/17/82	5	80	10.9	2.9
	11/23/82-2/12/83	81	11	0.6	1.1
20	1/4/83-2/3/83	30	17	72.6	8.8
	3/11/83-4/9/83	29	12	1.8	1.8
21	12/30/82-2/3/83	35	72	36.1	4.3

[1]Number of relocations

Six radioed hawks confined winter activities to well-defined ranges on the INEL Site. Ranges of hawks 12, 13, 16 and 17 were classified as seasonal ranges since these birds were monitored most of the winter period. For comparative purposes extensive premigratory movements of hawks 16 and 17 were excluded from seasonal range calculations to prevent grossly overinflated area estimates.

Areas and standard diameters of seasonal ranges varied significantly between hawks (Table 3). Female 13 occupied the smallest range of 70.2 km^2, although the loss of her radio in November may have resulted in an underestimation of range size from the inherent bias of visual locations after this date. Seasonal ranges of female 16 and male 17 were similar in size at 170.2 and

186.9 km^2 yet comprised about 33% of the 541.2 km^2 range occupied by male 12. Data relating to ranges of other radioed and wing-marked hawks are summarized in the appendix, Table 16.

Table 3. Data relating to seasonal ranges of four rough-legged hawks on the INEL Site.

Hawk	Inclusive Dates of Observation	No. of Days	n	Area (km^2)	Standard Diameter Diameter (km)
12	10/29/82-4/9/83	162	530	541.2	23.8
13	10/30/82-3/2/83	123	186	70.2[2]	5.6
16	11/20/82-2/23/83[1]	115	94	186.9	9.5
17	12/7/82-3/11/83[1]	105	246	170.2	6.8

[1]Excludes premigratory movements [2]Lost Radio 11/25/82

Standard diameters of the four seasonal ranges encompassed at least one major power line (Figures 6 and 7). Furthermore, the geographic activity centers of seasonal ranges fell within 3 km of power lines and highways for all hawks. Boundaries of some ranges also corresponded to the presence of power lines.

Although range overlap occurred in seasonal ranges (Figure 8), occupation of overlap areas for different hawks occurred at different times throughout winter. Thus limited interaction occurred between these four individuals. Areas occupied for several weeks during different winter periods were defined as weekly ranges.

Weekly Ranges

Weekly ranges were determined for four radioed hawks by manually plotting locations until major range shifts were seen to occur. Although periods of weekly range

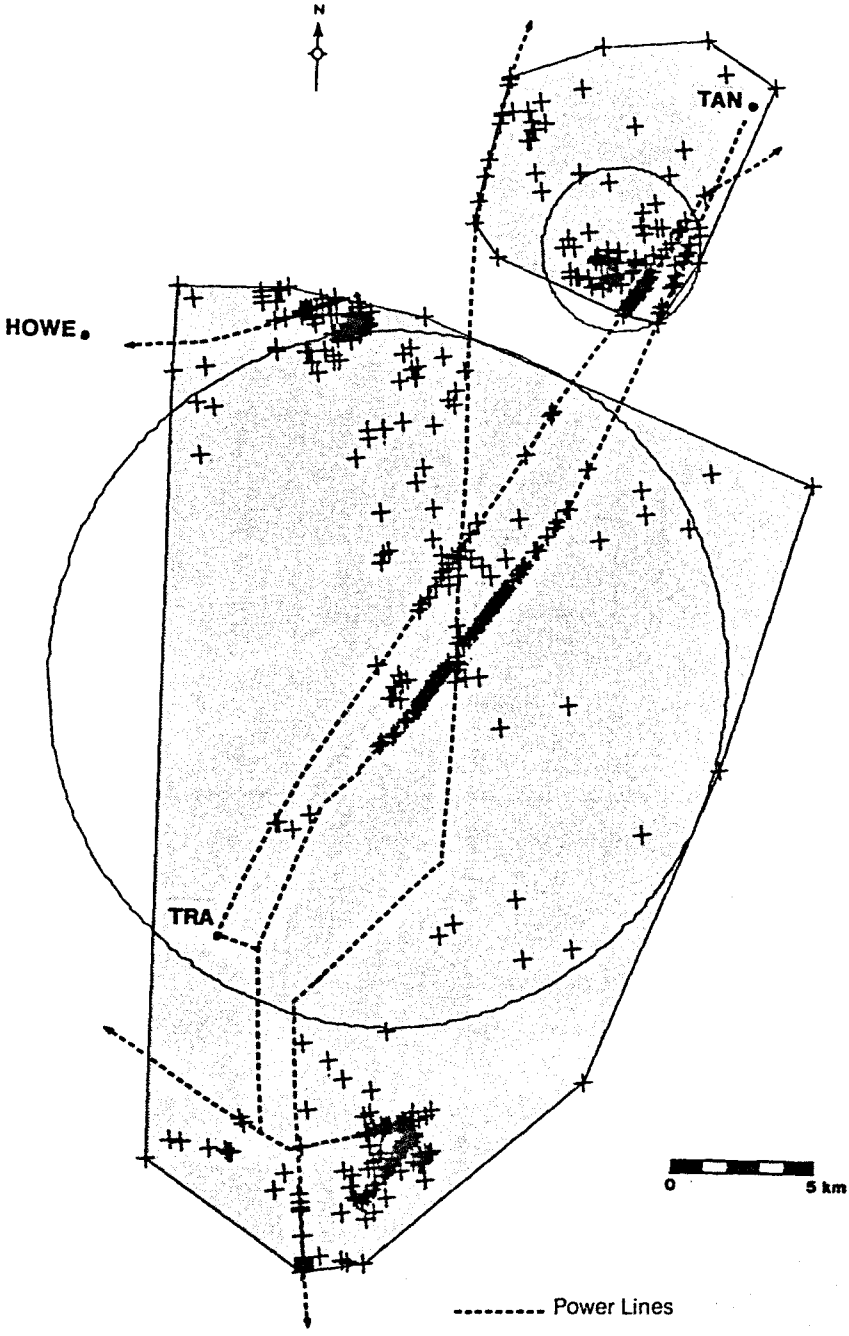

Figure 6. Relationship of major power lines to seasonal ranges of hawks 13 (above) and 12 (below) on the INEL Site. Circles represent standard diameters of ranges and crosses represent at least one hawk relocation.

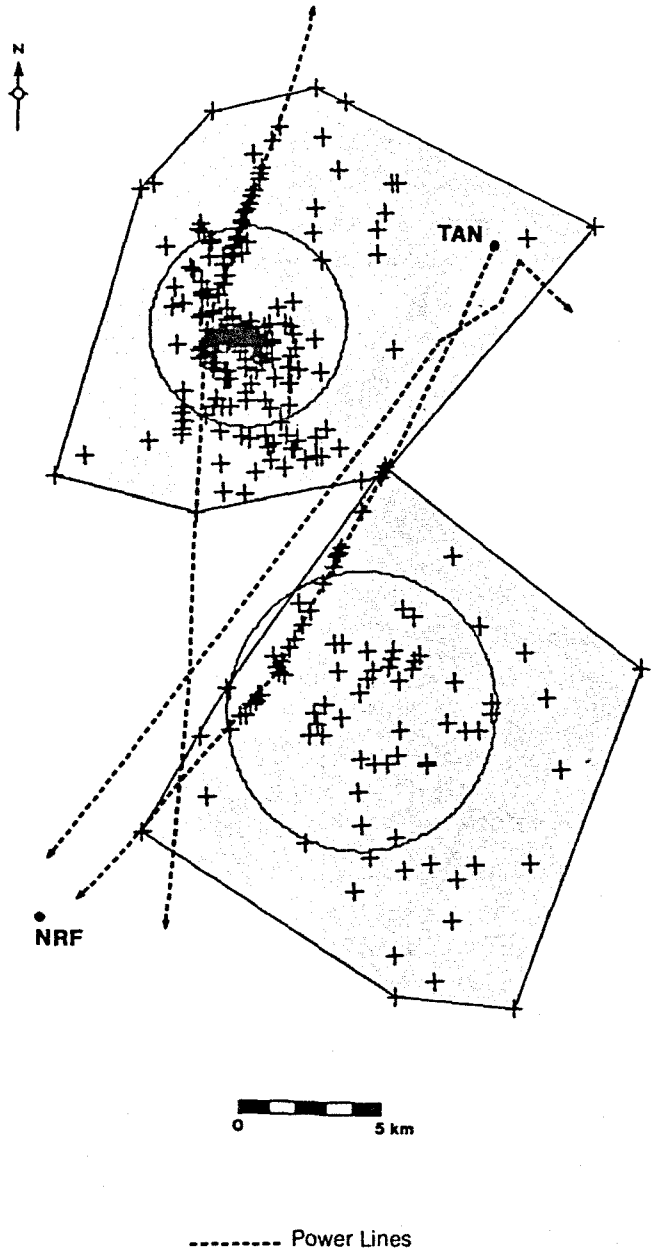

Figure 7. Relationship of major power lines to seasonal ranges of hawks 17 (above) and 16 (below) on the INEL Site. Circles represent standard diameters of ranges and crosses represent at least one hawk relocation.

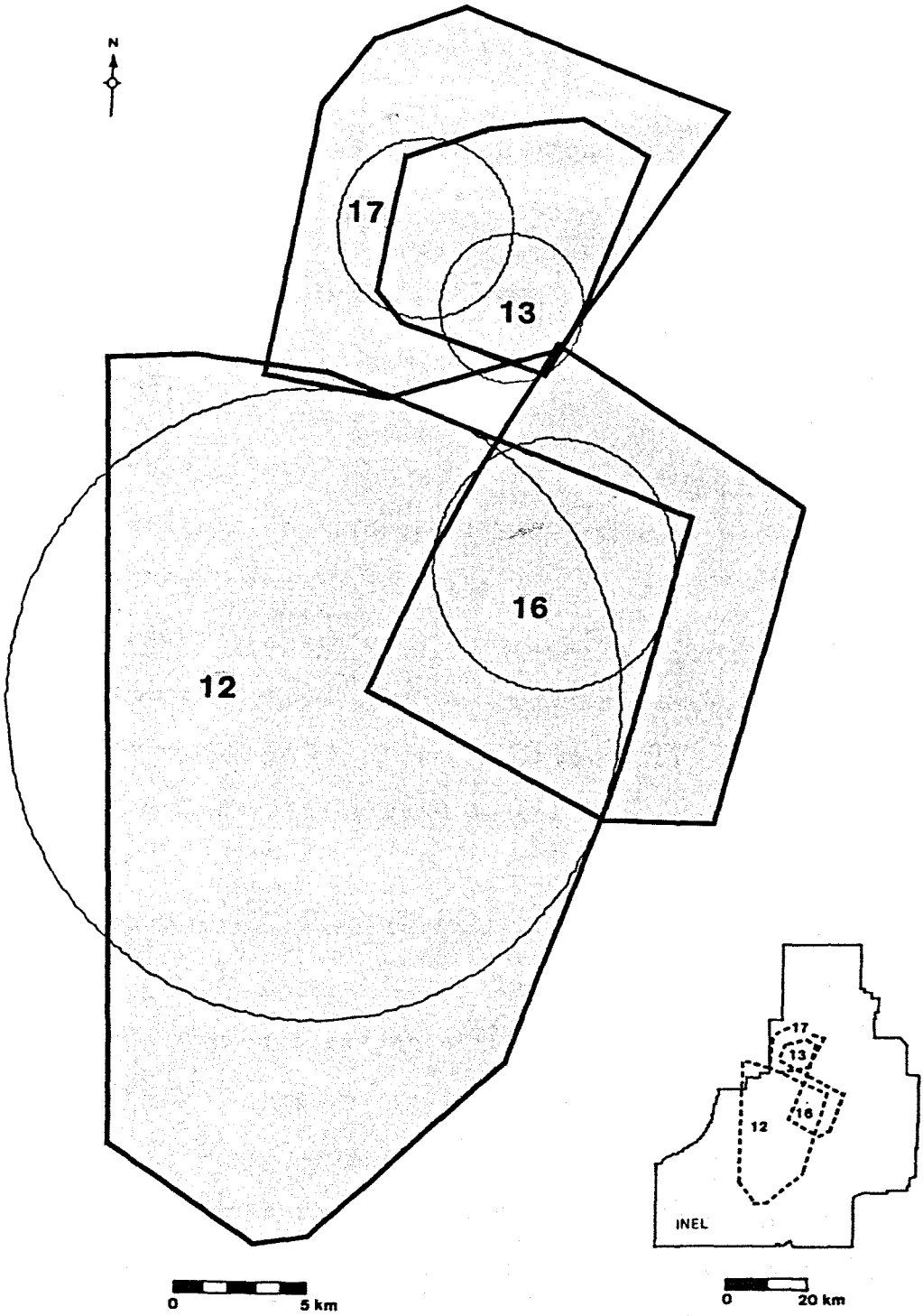

Figure 8. Seasonal range overlap of four rough-legged hawks on the INEL Site. Circles represent standard diameters of ranges.

occupation for these four birds did not conform exactly, at least six distinct winter periods of range occupation were evident from plot analysis (Table 4).

Range shift between the first four weekly ranges for all birds coincided with major weather changes over the Snake River Plain. Occupation of range 1 began when hawks were radioed, followed by period 2 that began 22 November when the first major northerly front lowered temperatures to -19.0 C, and 1 December when the first major southerly front dropped 33 cm of snow. Occupation of range 3 began after a northerly flow on 29 December which dropped temperatures to a seasonal low of -28.3 C. Occupation of range 4 began with the passage of a southerly front on 27 January and ended in mid to late February with declining snow depths and increasing temperatures.

Two features characterized mid-winter ranges 3 and 4 in the period of deep snow and low temperatures (Figure 2). First, although length of weekly range occupation was not identical, there was a clear trend towards reduced size from fall and spring ranges (Figures 9 and 10). Second, mid-winter ranges appeared to encompass favorable hunting areas. Hawks 12 and 13 hunted open-terrain grass-dominated habitat (Figure 9), and hawks 16 and 17 settled along major highways in shrub-dominated areas (Figure 10).

Table 4. Weekly ranges of four rough-legged hawks on the INEL Site during winter 1982-83.

	Hawk 12			Hawk 13			Hawk 16			Hawk 17		
Range	Inclusive Dates of Observation	n	Area (km^2)	Inclusive Dates of Observation	n	Area (km^2)	Inclusive Dates of Observation	n	Area (km^2)	Inclusive Dates of Observation	n	Area (km^2)
1	10/29/82-11/26/82	64	96.2	10/30/82-11/25/82[1]	116	61.8	11/20/82-11/26/82	25	60.5	—	—	—
2	11/27/82-1/1/83	29	319.0	11/27/82-12/31/82	39	23.5	12/3/82-1/6/83	28	102.5	12/7/82-12/31/82	87	121.9
3	1/3/83-1/27/83	70	26.6	1/4/83-1/27/83	21	2.3	1/7/83-1/25/83	17	34.5	1/1/83-1/25/83	75	36.0
4	1/28/83-2/13/83	74	6.4	2/1/83-3/2/83	10	2.3	1/27/83-2/23/83	24	73.6	1/27/83-2/18/83	36	23.9
5	2/14/83-3/3/83	215	108.7	—	—	—	2/24/83-3/4/83	61	861.9	2/19/83-3/11/83	42	70.5
6	3/4/83-4/9/83	78	144.8	—	—	—	3/5/83-4/14/83	18	1039.2[2]	3/14/83-4/9/83	15	167.3[2]

[1]Lost Radio 11/25 [2]Ranges encompass extensive premigratory movements

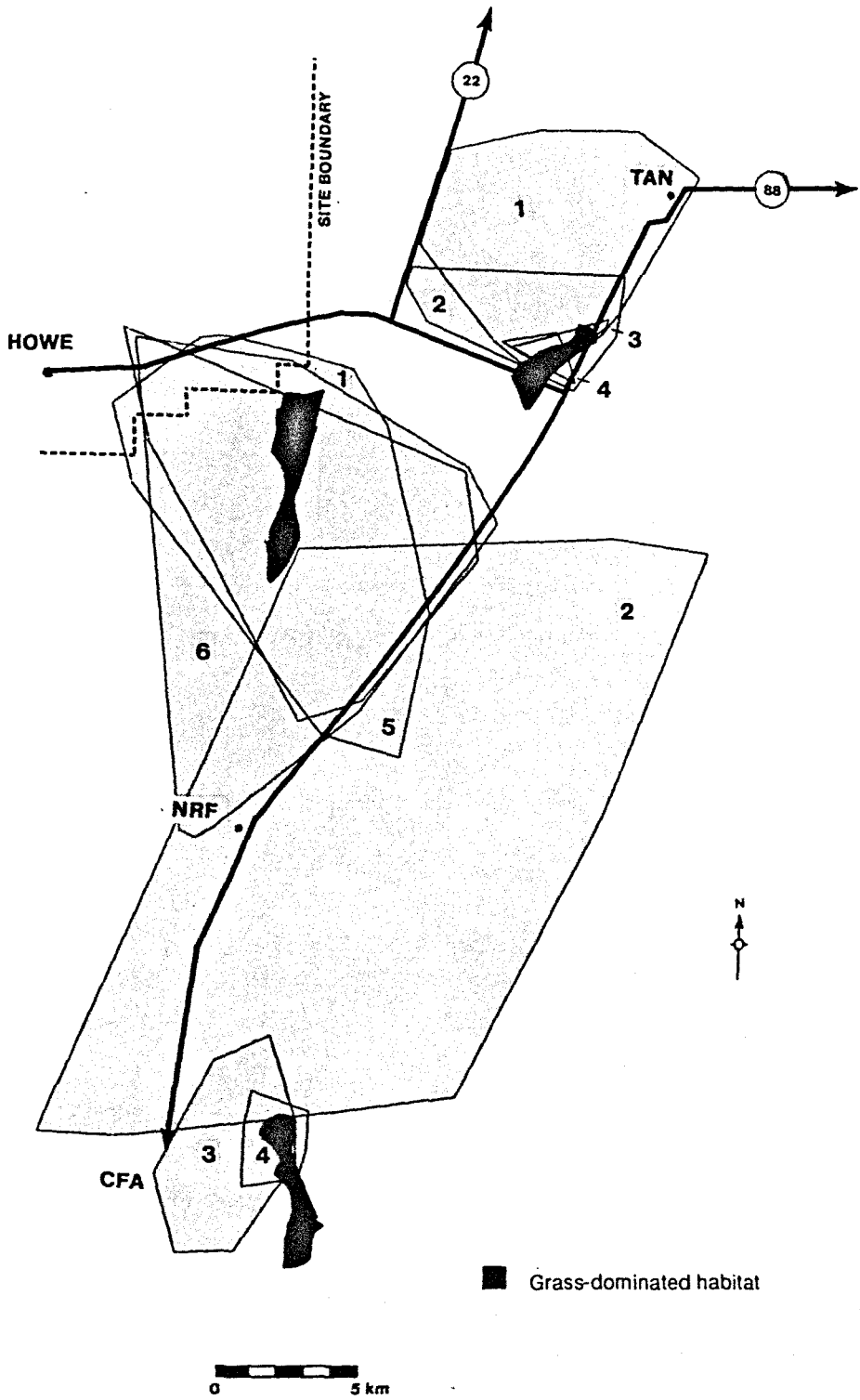

Figure 9. Weekly ranges of hawks 13 (above) and 12 (below) in relation to grass-dominated habitat on the INEL Site.

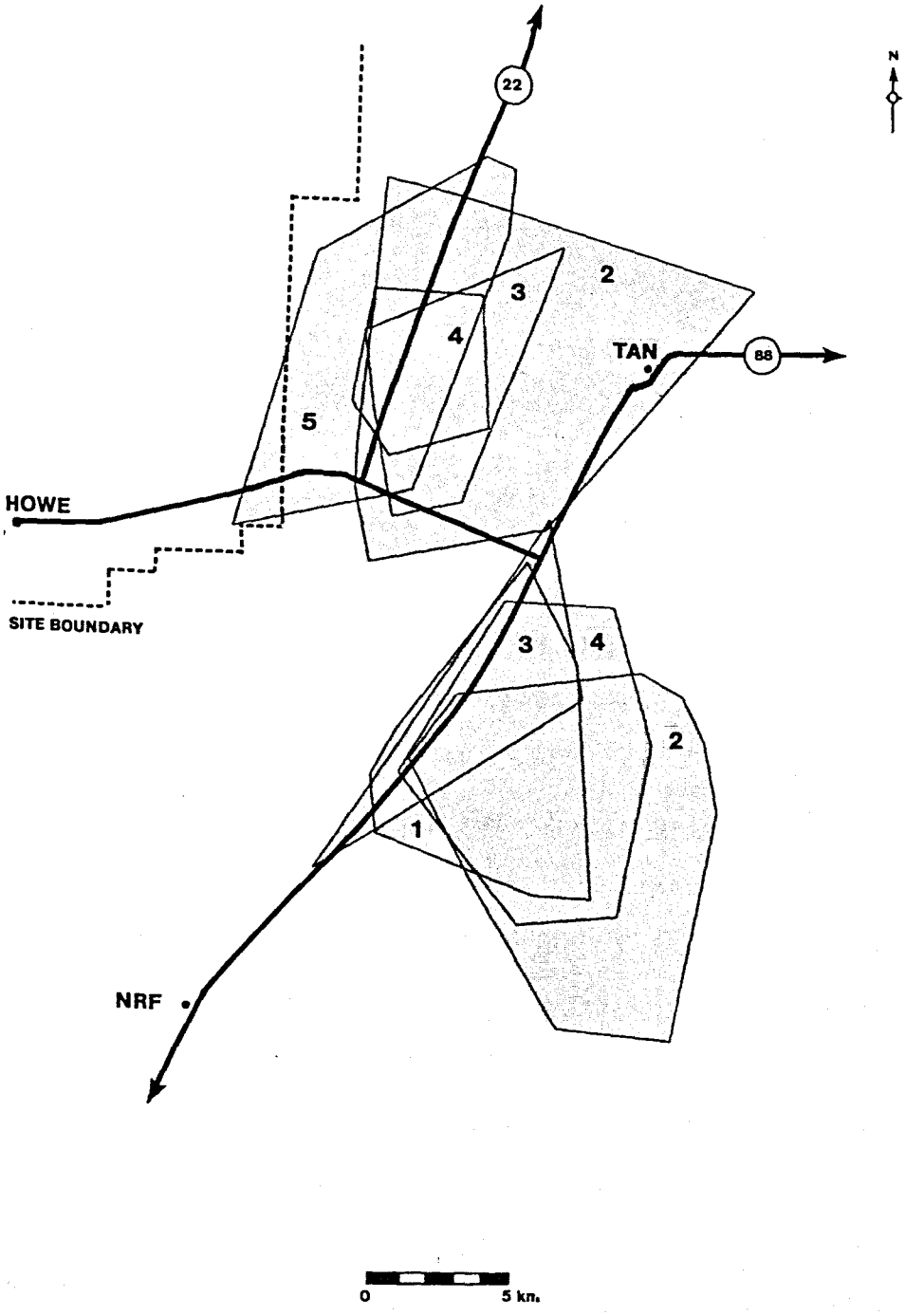

Figure 10. Weekly ranges of hawks 17 (above) and 16 (below) in relation to highways on the INEL Site.

Use of grass-dominated habitat for hawks 12 and 13 was greater than availability of this type on the whole seasonal range of both birds. Ten percent of combined ranges 3 and 4 and 38% of range 4 were dominated by wild rye (*Elymus cinereus*) yet grass-dominated cover types comprised only 5% of the seasonal range of hawk 12. Sixty-eight percent of the ranges occupied by hawk 13 for combined periods 3 and 4 was dominated by western wheatgrass (*Agropyron smithii*) yet grass-dominated cover types comprised only 6% of the seasonal range.

Hawks 12 and 17 adopted different feeding strategies while on mid-winter ranges. Hawk 12 did not feed on carrion but attempted six strikes on small mammals during 36.4 hours of observation. Hawk 17 fed eight times on rabbit carrion and attempted one small mammal kill during 34.8 hours of observation. This hawk scavenged road-killed and predator-killed jack rabbits near a belt of junipers where hundreds of jack rabbits had taken refuge from deep snow. Observations of hawks 13 and 16 were considered too limited to describe trends in feeding behavior on mid-winter ranges.

Combined mid-winter ranges of hawks 16 and 17 on shrub-dominated habitat were 78% larger than ranges of hawks 12 and 13 on grass-dominated areas. However, limited observations of hawk 13 and short duration of range 4 by hawk 12 make size comparisons suspect.

Weekly range overlap of hawk 12 was less than that observed for other birds which partially accounted for the larger seasonal range of this hawk. Weekly Range 2 connected mid-winter ranges 3 and 4 to fall range 1 which was several kilometers south (Figure 9). In spring hawk 12 displayed fidelity to fall range 1 and returned north to this area.

Time Budgets of Hawks on Weekly Ranges

Observations of all radioed hawks were divided into five groups generally corresponding to weekly range periods with the exception of periods 5 and 6 which were combined (Table 5).

Table 5. Periods used to determine weekly time budgets of rough-legged hawks.

Period	Inclusive Dates	Hours of Observation
1	10/29/82-11/26/82	67.7
2	11/27/82-1/1/82	34.5
3	1/2/82-1/27/83	54.8
4	1/28/83-2/24/83	141.2
5	2/25/83-4/14/83	114.4
	Total	412.6

Analysis of 412.6 hours of observation showed radioed hawks spent increased time perch-hunting and decreased time preening and in flight during mid-winter (Figure 11). Time spent perch-hunting was approximately 8% greater in period 3 than in periods 1 and 5. Of 355.4 hours spent perch-hunting for combined periods, 70.1%, 25.6% and 4.3% was from utility poles, rocky outcrops or sagebrush and

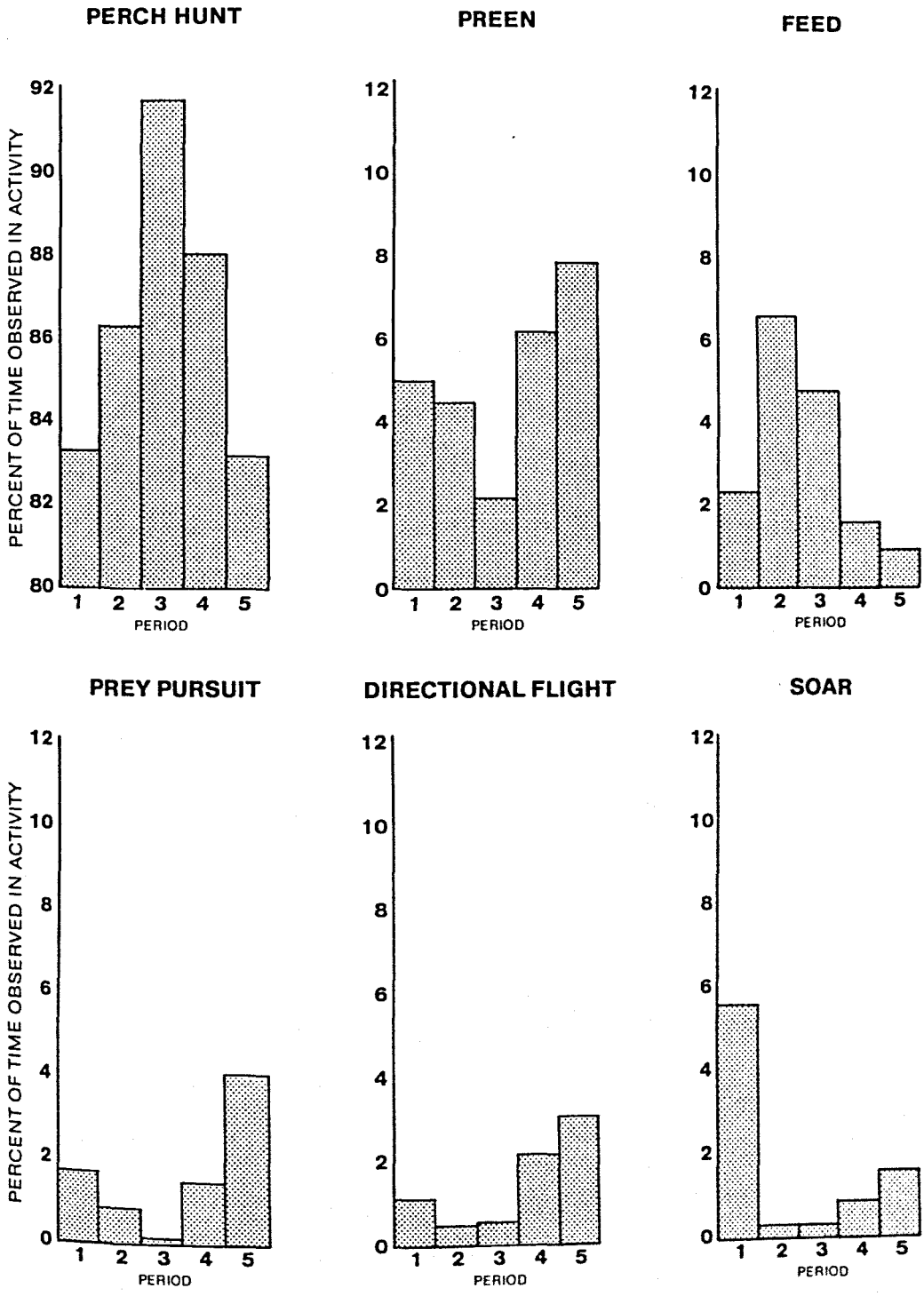

Figure 11. Changes in rough-legged hawk activity over five weekly periods in winter 1982-83. Data are based on 412.6 hours of observation.

miscellaneous substrates, respectively. However, use of hunting substrates changed over weekly periods. Time spent hunting from utility poles in periods 2 and 3 (47.5%) relative to the other substrates was significantly different from the remaining periods (76.7%) (X^2=5.10, $p<0.001$).

Increased time spent feeding in periods 2 and 3 corresponded to increased use of carrion during that time. Analysis of 95 feeding observations throughout the winter showed a significant difference in frequency of carrion and live prey use in these two periods (80.8%) compared to the remaining periods (31.4%) (X^2=18.60, $p<0.001$). Whereas hawks bolted or dismembered and consumed small mammals within 3 minutes of capture, episodes of carrion feeding extended up to 40 minutes as a result of the larger size of carcasses and the difficulties hawks encountered when feeding on frozen carrion.

Time devoted to flight activities varied less than 5% during winter. Although less time was devoted to flight activities in mid-winter, mean duration of prey pursuit and directional flights increased during these periods (Figure 12). Hawks spent about 2 minutes longer in episodes of mid-winter prey pursuit and over 1 minute longer in travel between perches than in fall and spring. This difference corresponds to the contrasting foraging techniques associated with small mammal pursuit and

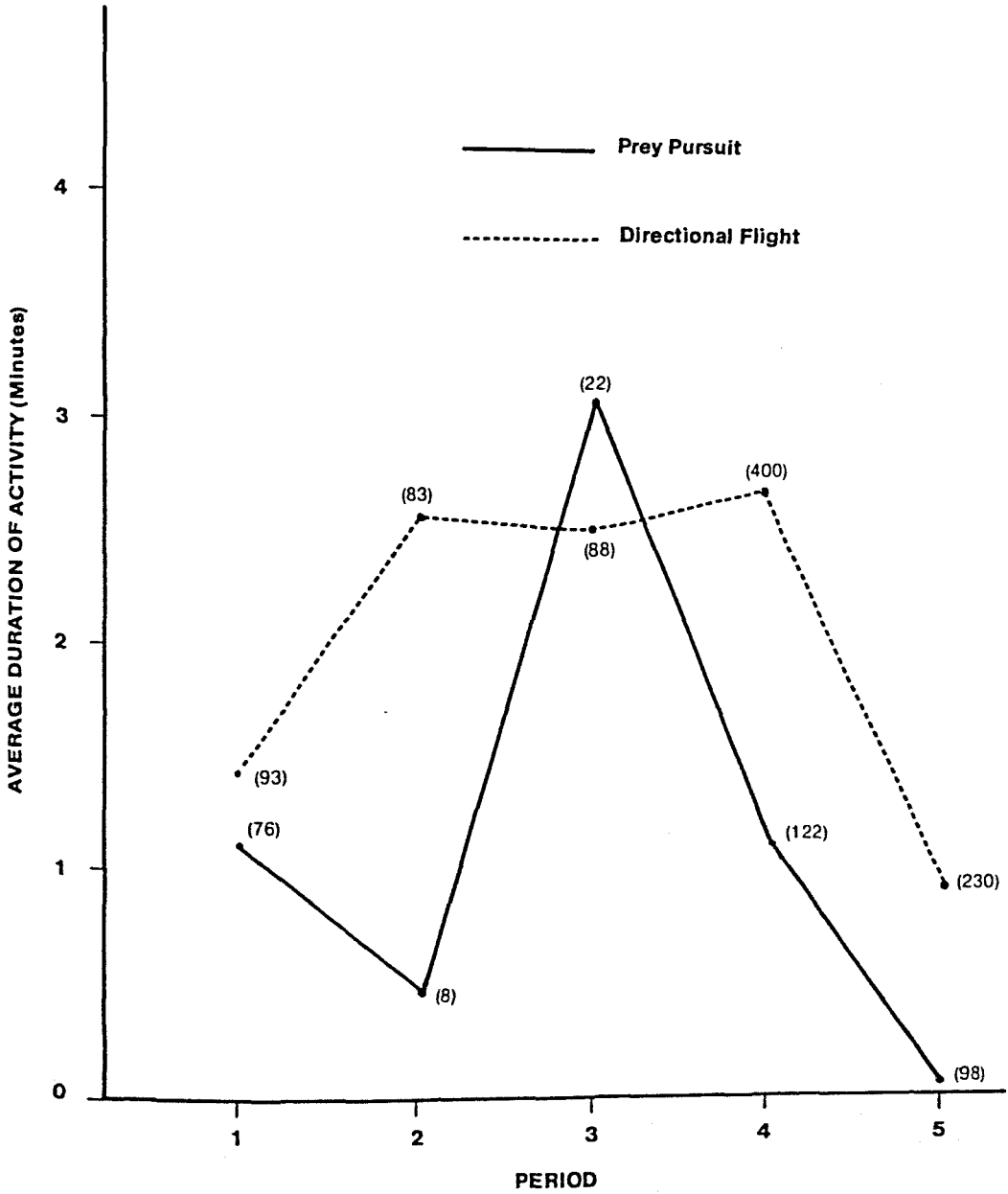

Figure 12. Changes in average duration of prey pursuit and directional flight of rough-legged hawks over five weekly periods. Numbers in parenthesis indicate frequencies of observation.

carrion feeding between winter periods. When carrion feeding, hawks travelled long distances to located carcasses and would return to feed as opportunity allowed. However, when pursuing small mammals along power line corridors, hawks made relatively short flights from and between adjacent utility poles.

Daily Ranges and Activity Patterns

Because of restricted access and radio loss, radioed hawks were monitored at different degrees of intensity throughout winter periods. Thus seasonal changes in daily movements (Appendix, Table 17), were not subjected to group analysis. However, the shortest movements and smallest ranges from 47 daily movements occurred in winter, while high values occurred in spring (Table 6). Mean total daily movement for the 47 days was 14.1±8.5 km, and daily ranges averaged 8.6±10.1 km^2.

Table 6. Extreme values of data relating to 47 roost to roost movements of eight rough-legged hawks. Dates of statistics are given in parenthesis.

Total Distance Moved (km)	Area (km^2)	Maximum Distance Moved Between Locations (km)	Mean Distance Moved Between Locations (km±S.D.)
2.9(1/18)-[1] 37.5(3/9)	4.0(2/17)- 48.6(3/9)	0.9(2/17)- 17.4(2/25)	0.2±0.2(2/10)- 4.2±3.5(3/9)

[1]Excludes incomplete daily movement of hawk 22 on 14 march of at least 120 km.

To illustrate the variability in daily movements which may be partially related to conditions in weekly periods, two roost to roost movements of hawk 12 are

mapped in Figure 13. On 8 February this hawk remained perched for 7.6 hours or 95.0% of observation time. He was observed to travel seven times between perches, attempted no small mammal strikes and was not observed to feed on carrion although he was lost from view while on the ground for 35 minutes. On 3 March the same hawk spent 7.6 hours or 88.4% of observation time in perching activities. He was observed to travel 18 times between perches and made three successful small mammal kills on six attempted strikes. Total distance moved on 8 February was less than on 3 March (5.5 and 19.3 km respectively), as was daily range (1.4 and 12.9 km^2), maximum distance moved (1.4 and 5.9 km) and mean distance moved (0.5±0.5 and 0.8±1.4 km). Snow depth and mean daily temperature on 8 February and 3 March were 12.7 and 5.0 cm and -4.2 and 3.6 C, respectively.

Although time devoted to different activities varied throughout winter, rough-legged hawks exhibited consistent diel patterns of behavior (Figure 14). Hawks devoted over 97% of the first two hours after sunrise to perch hunting and preening. Hawks usually flew short distances from roosts to utility poles or remained at roosts and perched with backs to the sun in early morning.

Between 2 and 4 hours after sunrise hawks increased all activities except perch-hunting which declined by about 10%. Hawks usually flew from roosts to frequented

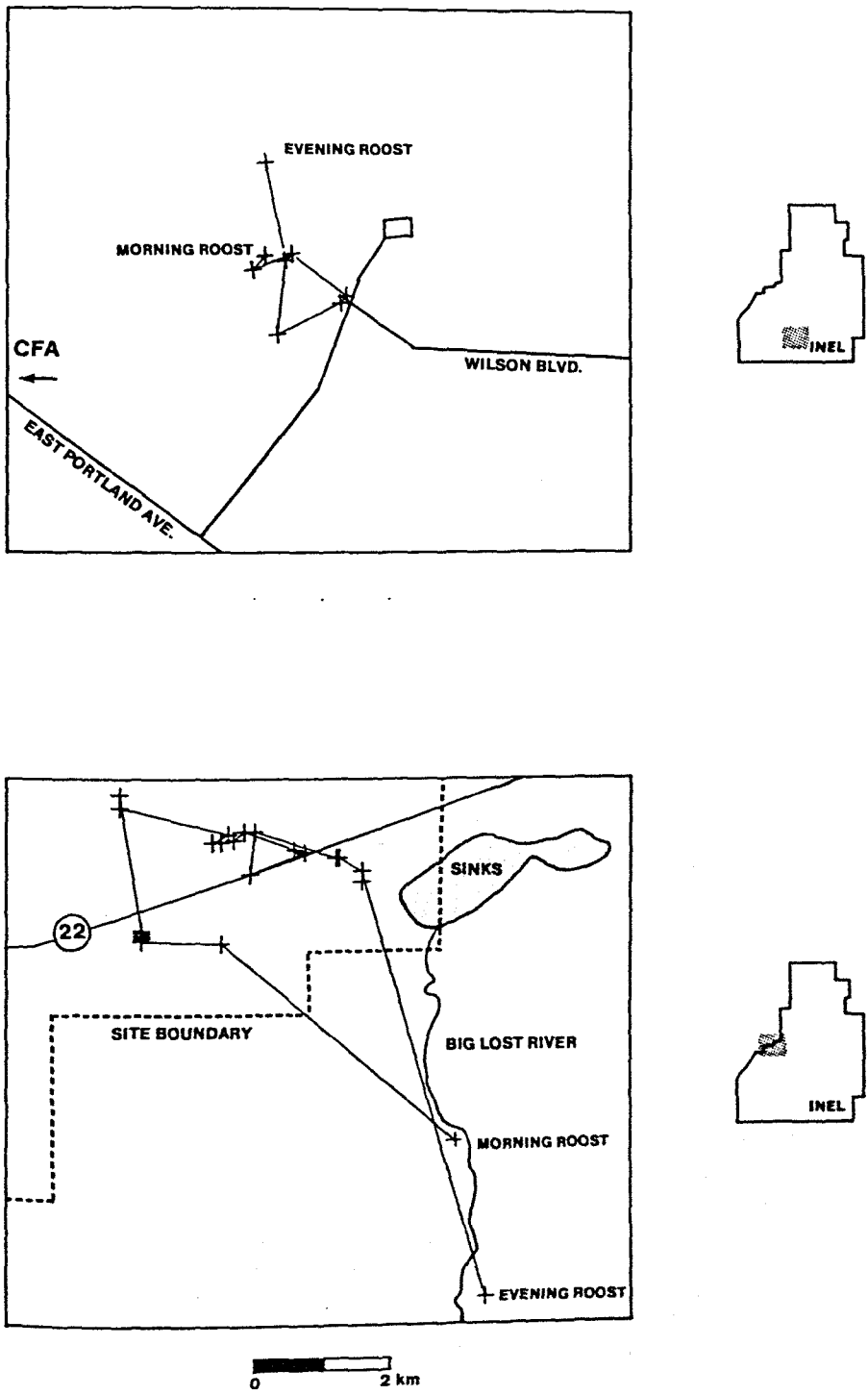

Figure 13. Contiguous roost to roost movements of hawk 12 on 8 February (above) and 3 March (below). Each cross represents one perching location.

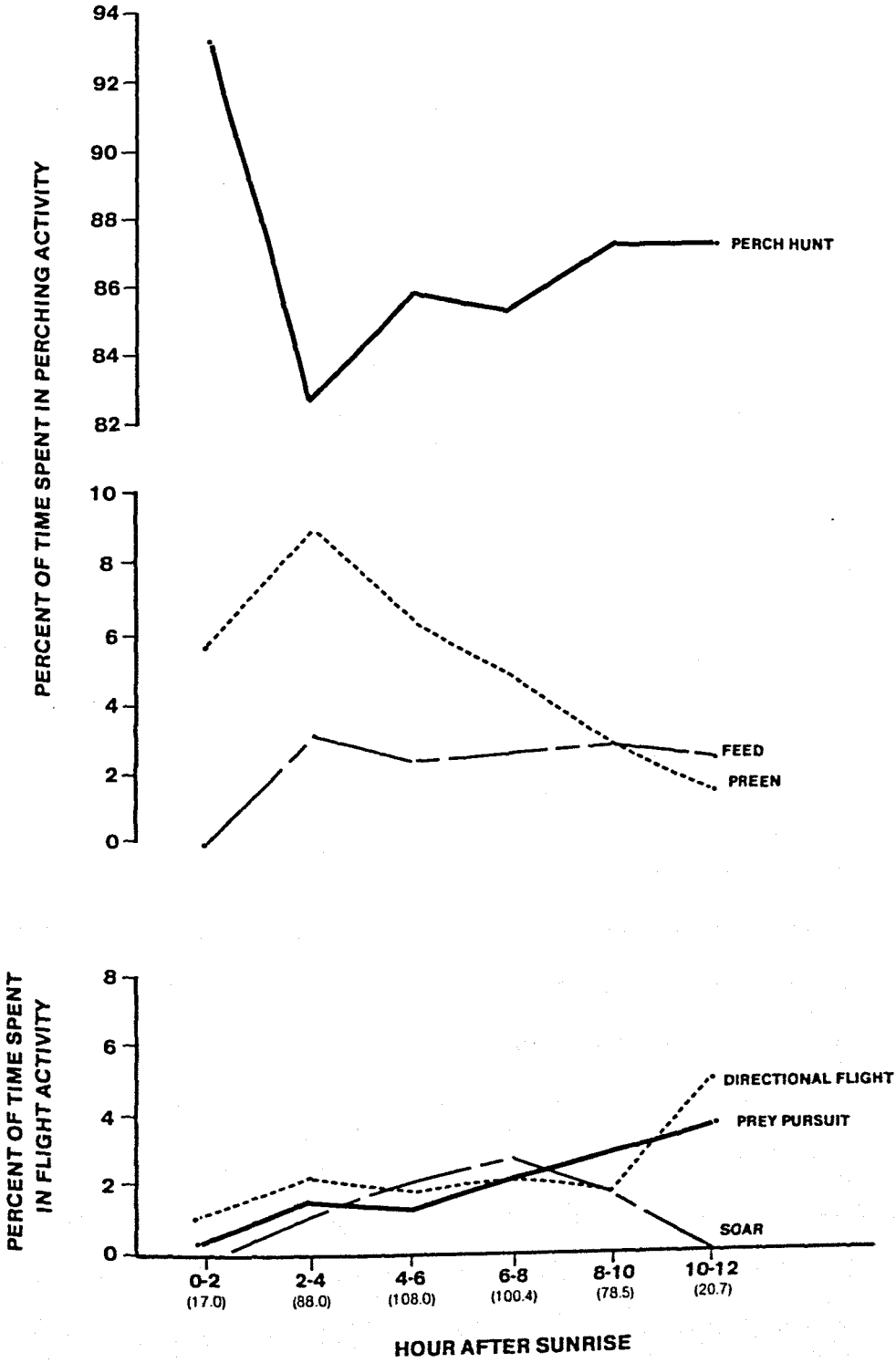

Figure 14. Diel activity patterns of rough-legged hawks based on 412.6 hours of observation. Total hours of observation for each 2 hour period are given in parenthesis.

power lines to pursue prey or began to soar on warm days. Peak soaring occurred in mid-afternoon and ended by late afternoon.

Perch-hunting proceded in a predictable pattern. Hawks progressed along a power line and moved to adjacent poles after attempted strikes or after hunting from the same pole for several minutes. Thus, configuration of power lines in a given area influenced daily movement patterns, which over time, also affected the shape and size of weekly ranges.

This relationship is illustrated on ranges of hawks 22 and 23 occupied 21 January to 25 February (Figure 15). Power line configurations and daily movements for these two hawks were in a linear and circular pattern, respectively. Likewise, weekly ranges of these two birds conformed to linear and cuboid shapes. Furthermore, the range of hawk 23 was smaller than and comprised 19.9% of the range area of hawk 22. This size difference may be partially attributed to the different arrangement of power lines on these ranges.

From the fourth hour after sunrise throughout the rest of the day hawks devoted more time to perch-hunting, directional flight and prey pursuit and less time to preening. Hunting activity peaked in late afternoon and evening although time devoted to feeding varied little throughout the day. This indicated hawks were less

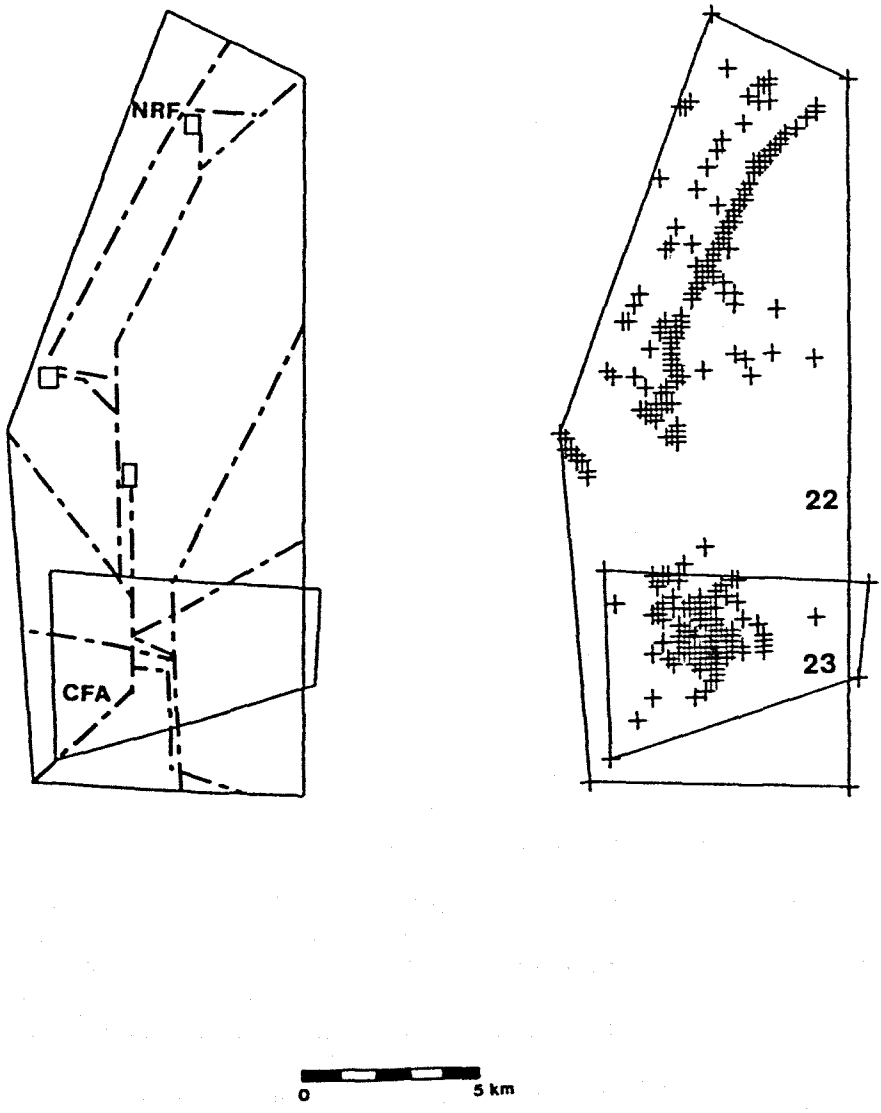

Figure 15. Relationship of utility pole configuration (left) to ranges of hawks 22 (n=336) and 23 (n=354) (right) occupied from 21 January to 20 February. Each cross represents 1 to 26 relocations.

successful hunting later in the day, but what was interpreted as perch hunting behavior may have included greater time spent resting as the day progressed, resulting in inflated perch-hunting estimates.

Increased time spent in directional flight the last hours of the day was due to hawks returning to roost sites. Hawks occasionally would course along major roads scanning for carrion while flying to roosts.

Social Interaction

Intra and interspecific interactions of rough-legged hawks were observed both winters. Active responses of individuals to the presence of other raptors followed one of two patterns. Aggressive responses involved a direct flight to the "intruding" raptor in an attempt to displace it from carrion or perch. One displacement frequently resulted in a series of interactions between closely perched hawks. Displacement was infrequently followed by brief aerial escort by the dominant bird from the point of interaction but more often involved claiming the perch of the displaced bird. Non-aggressive displacement observed between male and female rough-legged hawks was followed by flight chase and infrequent talon grappling. Mutual displacement following reperching indicated the non-competitive nature of this type of interaction.

The flight approach preceding an aggressive displacement was headlong toward the "intruding" raptor,

whereas non-aggressive displacements were generally executed from a wide approach. On several occasions raptors appeared to anticipate aggression from another perched raptor and left their perches the instant the dominant bird took flight. On other occasions raptors would not yield perches or prey to dominant birds and would crouch in an effort to prevent being displaced. Rough-legged hawks were struck on at least three such occasions by dominant hawks.

Vocalization by dominant rough-legged hawks preceded displacement of hawks on two occasions. A juvenile hawk was observed to emit a series of two to three alarm calls every 15 seconds for about 1.5 minutes prior to displacing an adult male. The scream was similar to a faint red-tailed hawk alarm call. On two other occasions the same juvenile gave alarm calls while circling the observation vehicle which was parked about 100 m away. On 25 October during trapping procedures an adult female that perched above a carrion-baited noose carpet gave two alarm calls and displaced a juvenile that alighted on an adjacent utility pole.

Of 102 observed intraspecific interactions, 95 (93.1%) resulted in successful displacement. Of successful displacements, 35 (36.8%) appeared to result from defense of prey, 8 (8.4%) were non-aggressive encounters and the cause of the remaining 52 (54.7%) was unknown. The nature

of interaction also appeared related to the sexes of interacting birds (Table 7). Of 76 successful intraspecific displacements where sexes were identified, 70% involved females displacing males from perches or carrion. In only 5% of interactions were males observed to displace females and all four encounters were determined to be non-aggressive encounters.

Table 7. Intraspecific interactions of rough-legged hawks observed during combined winters of study.

Sex of Displacing Hawk	Sex of Displaced Hawk	Number of Encounters
Female	Female	12
Female	Male	53 (7)[1]
Male	Female	4
Male	Male	7

[1]Parenthesis indicate unsuccessful displacement

Social interaction of radioed hawks showed that they most intensively defended perch sites or carrion near their seasonal activity centers, with greater tolerance of intruders outside this area. However, raptors within relatively short flight distances (i.e. 500 m) were pursued by dominant hawks on established ranges. The only evidence of actual range defense involved female 4 in March 1982. On three occasions she displaced different hawks and escorted each 300 to 500 m to the same geographical boundary before returning to her original perching area.

A series of interactions on 14 December illustrate the complexity of intra and interspecific interactions as they

relate to sex and ranges of interacting hawks. At 1045 h male 17 unsuccessfully attempted to displace female 13 from a utility pole within 0.1 km of the geographic activity center of her seasonal range (Figure 8). A golden eagle (Aquila chrysaetos) displaced both perched hawks 12 minutes later and the hawks perched on nearby poles. After 66 minutes hawk 17 flew about 100 m south to the highway and displaced a northern harrier (Circus cyaneus) from a rabbit carcass, but was displaced himself by hawk 13 after feeding for only a few seconds. Hawk 13 fed for several minutes and displaced 17 from a nearby sagebrush perch who then flew west and vacated the area. The following day, however, both hawks perched passively for several minutes within 5 m of each other on the overlapping portions of the standard diameters of their ranges.

On two other occasions female 13 displaced male 17 near the activity center of her range but later the same day perched passively with him on the eastern boundary of the range's standard diameter.

Extensive displacement of two marked hawks occurred after they inhabited new ranges. After female 21 moved into the CFA in late December she interacted with three resident female hawks 11 times until 3 February. Each interaction resulted in displacement of hawk 21 from

utility poles. These were the only female to female interactions recorded in this study.

Between mid-February and the beginning of March, hawk 12 made several daily movements onto off-Site agricultural land, returning to roost on-Site in the evening. His first movement into this area on 15 February was to a power line that bisected the agricultural land. During a 10 minute period starting 15 seconds after arrival, he was displaced six times by two adult males and one juvenile hawk that were recognized as residents of this area from repeated sightings. Hawk 12 then flew southeast to another power line on agricultural land near the Site boundary. For the remainder of the season, while on farmland, he primarily hunted a 1.5 km^2 area encompassing this power line where he experienced minimal social interaction (Figure 6).

Rough-legged hawks exhibited different responses to different raptor species during interspecific encounters (Table 8). Golden eagles displaced rough-legged hawks of both sexes from prey and perches on 13 occasions while rough-legged hawks failed to displace golden eagles on five attempts. Golden eagle dominance was exerted near the activity centers of females 4 and 13. On 13 December at 1600 h, hawk 13 perched on an H-type power pole near the activity center of her range. An adult golden eagle on an adjacent pole emitted six alarm calls while facing

the hawk. Calls were repeated about 30 seconds later at which time hawk 13 took flight. The eagle then flew to the same perch and side-stepped to the inside of one pole to roost. Similar incidents occurred on 25 and 27 January 1982. An immature golden eagle was observed to displace female 4 from a tree perch on a range she occupied for at least four weeks. After being displaced in both instances this hawk made several unsuccessful stoops in an apparent attempt to displace the eagle.

Table 8. Interspecific interactions of raptors observed during combined winters of study.

Displacing Raptor	Displaced Raptor	Total
Golden Eagle	Rough-legged Hawk	13
Bald Eagle	Rough-legged Hawk	1
Rough-legged Hawk	Common Raven	1
Rough-legged Hawk	Northern Harrier	3
Rough-legged Hawk	Prairie Falcon	1
Rough-legged Hawk	Red-tailed Hawk	(1)[1]
Rough-legged Hawk	Golden Eagle	(5)
Northern Harrier	Rough-legged Hawk	(1)

[1]Parenthesis indicate unsuccessful displacement

Limited rough-legged hawk interactions with other raptors were observed. On 31 December an adult bald eagle (*Haliaeetus leucocephalus*) displaced hawk 17 from a rabbit carcass near the center of his range. Rough-legged hawks displaced northern harriers from rabbits on three occasions while displacement of a rough-legged hawk by a northern harrier was unsuccessful. A rough-legged hawk successfully displaced a prairie falcon (*Falco mexicanus*) and unsuccessfully a red-tailed hawk from utility poles in incidents apparently not related to prey defense. Common

ravens (Corvus corax) were observed to mob rough-legged hawks on several occasions. Interaction usually involved short stoops on the hawk while it was feeding on the ground or in travelling flight. Aerial prey robbery by two ravens was observed on 10 March. One raven pursued and struck the hawk from above. When the hawk presented its talons in flight the prey was dropped about 50 m and captured in mid-air by the second raven.

Not all interspecific encounters were antagonistic in nature. Rough-legged hawks, golden eagles and ravens were frequently seen soaring together in fall and late spring. Interspecific feeding behavior was observed once. On 10 January 1982 a golden eagle and rough-legged hawk fed passively together for several minutes on an unidentified carrion source. Although perched within 2 m of each other, no threat behavior was displayed by either raptor.

Roosting Behavior

Radioed hawks were observed to roost on two substrates. Of 79 recorded roost sites, 39 (49.4%) were on sagebrush, while the remaining 40 (50.6%) were on H-type poles supporting high-voltage transmission lines. Hawks roosted on sagebrush in the open desert at least 500 m from major roads. Perching was not atop sagebrush, but generally on side branches near the ground. To roost on utility poles, hawks perched on the cross beam and side-stepped to the inside edge of one supporting pole

where they were often difficult to see. Hawks roosted on utility poles as close as 50 m from major roads. No hawks were observed to roost communally or even within several hundred meters of one another.

Although no seasonal trends in roost preference were observed, there was a difference in windspeed at roosting time between ground (n=41) and pole roosts (n=37) (t=2.25, p=0.031). Windspeed at roosting time averaged 1.47±1.02 and 0.83±0.62 meters per second for ground and pole roosts, respectively. Hawks occasionally flew to ground roosts when windspeed increased a few minutes after they had already roosted on utility poles. Air temperature at roost time was not different between ground and pole roosts (t=1.27, p=0.214).

Flights to roost for 51 roosting episodes ranged from 73 minutes before to 22 minutes after sunset. A regression of roost time on length of day was non-significant (F=0.96, p=0.332) and yielded a regression coefficient of -0.067. Hawks did not roost earlier as day length increased. However, roosting time appeared related to hunt success during the day. Hawks known to have fed successfully frequently went to roost early regardless of day length. This was especially evident after hawks consumed large quantities of carrion.

Little night movement was believed to have occurred after hawks roosted. In most cases where hawks were

located at evening roosts they were found at identical locations the following morning. During all-night monitoring on 5 November, hawk 13 remained on the same sage perch under a moonlit sky, although winds gusted over 32 KPH.

All radioed hawks displayed fidelity to roost sites and flew as far as 5 km from hunting areas to roost. Of 79 known roost locations, 41 (52%) were within several meters or at the identical location of another roost of the same bird. Hawk 23 roosted on the same utility pole at least 14 times over 22 nights in late February/early March. For approximately three weeks during the same period hawk 12 roosted in one of two areas several kilometers from daily hunting ranges (Figure 9). He roosted in one area 3 km south of the Big Lost River Sinks following daily hunting forays in agricultural land and in the second area, 7 km to the south, following daily hunts along Lincoln Boulevard to the east. Hunting between the two ranges was alternated every one or two days.

Hunting Success

Rough-legged hawks hunted live prey by two techniques. Of 311 observed strikes by radioed hawks, 49 (15.7%) were from hover flight and the remaining 262 (84.3) from still perches. Hover flight generally occurred on days with windspeed at least 16 KPH which allowed hawks to maintain nearly a stationary position

while flying into the wind. Excessive wind velocities (i.e. in excess of 50 KPH) forced hawks to perch on sagebrush or the ground. Perch-hunting involved hawks visually scanning the ground for nearby and distant prey. Exhaustive descriptions of rough-legged hawk hunting techniques are given by Bildstein (1978) and Smith (1979).

Success of strikes initiated from hovering (2.0%) was different from strikes initiated from still perches (26.0%) (X^2=13.75, $p<0.001$). Overall hunt success was 22.2% (n=311). However, hunt success varied between different vegetative cover types. Success declined from 42.2% (n=26) to 26.7% (n=45), 19.4% (n=216) and 12.5% (n=24) between matted alfalfa, grass-dominated, sagebrush-grass and sagebrush-shrub habitat, respectively. Hunt success in matted alfalfa was different from success in non-agricultural areas (X^2=8.50, $p<0.050$).

Time spent perch-hunting varied for substrate height. Of 355.4 hours observed, radioed hawks spent 106 hours (29.9%) hunting from perches 0 to 2 m above ground, 167 hours (46.9%) from 2 to 11.5 m and 82.4 hours (23.2%) above 11.5 m. There was no difference in time spent hunting from perches 2 to 11.5 and 11.5 m and above based on their relative availabilities (62 and 38%, respectively) (X^2=2.43, $p>0.100$). The virtually unlimited availability of ground perches resulted in less than proportionate use of the 0 to 2 m class. Hawk 22 was

observed to perch hunt from a radio tower 40 m above ground on two occasions but was unsuccessful on three attempted strikes.

Hawks continued to hunt small rodents despite snow cover. Of 278 observed strikes with at least 10 cm of snow cover, 56 (20.1%) were successful. However, as noted previously, the reduction in hunt attempts and increased carrion use in weekly periods 2 and 3 indicated hawks attempted fewer small mammal kills at snow depths greater than 12 cm.

Low hunt success may have been a factor influencing movement of hawk 15 from the Site in late fall. During 14 hours of observation prior to movement this hawk was successful on only 1 of 33 (3.0%) attempted strikes. On the evening before leaving the area hawk 15 successfully located and fed on rabbit carrion at 1745 h and appeared gorged before roosting. The following day this hawk began an extensive northward movement to a major highway in an area where abundant rabbit carrion was noted throughout the remainder of the winter.

Premigratory Movements

Prior to spring migration hawks 16, 17 and 22 exhibited extensive movements from winter ranges. These movements were distinguished from other range shifts during winter by their length, short duration and consistent northward orientation.

Extensive movements of two hawks began the day that the first migrant red-tailed hawks, ferruginous hawks (*Buteo regalis*) and prairie falcons were observed on the Site. On 25 February hawks 16 and 22 perched on utility poles 0.5 km south of the NRF in the central portion of the winter range of hawk 22. Between 1200 and 1300 h a migrant red-tailed hawk moved northward along the power line toward the perched hawks. After the red-tailed hawk perched within several meters of both rough-legged hawks, hawk 16 took wing, kettled and was lost from view. Twelve minutes later hawk 22 attempted to displace the red-tailed hawk and then flew northeast. Neither rough-legged hawk was located the following day but on 27 February both were observed 20 km northwest near Howe, Idaho.

Hawk 22 returned to the Site on 1 March and made at least three movements up to 60 km from his winter range prior to the last location 6 April (Figure 16). Maximum time away from the range was four days including a 1 day movement of over 120 km. Extreme movements north up the Little Lost River Valley to May, Idaho, were into an area dominated by farmland where as many as 13 rough-legged hawks were observed at one time. One return movement to the Site on 29 March included flight over the Lemhi Mountains.

Hawks 16 and 17 exhibited less extensive premigratory movements (Figure 17). Hawk 16 returned to her winter

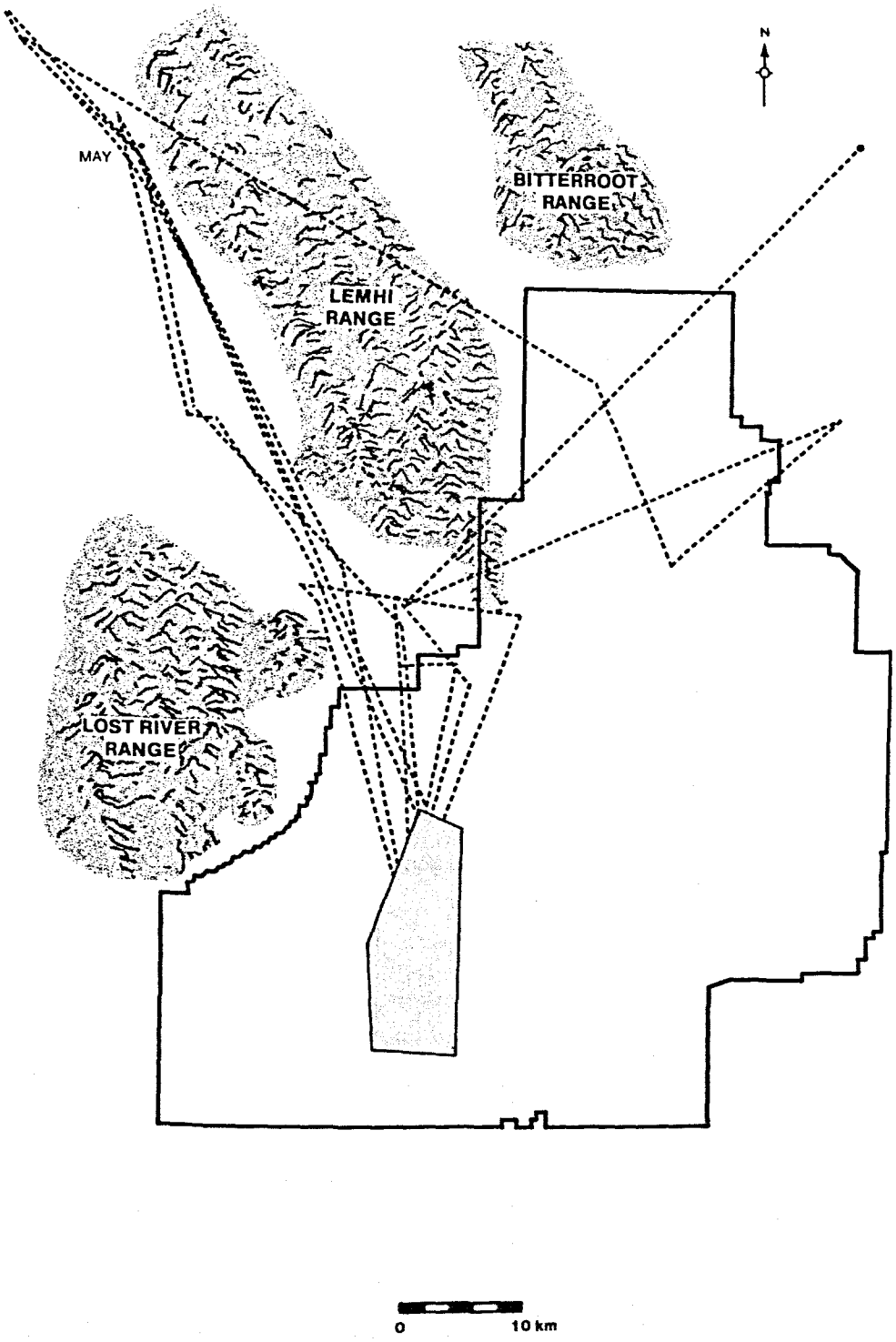

Figure 16. Premigratory movements of hawk 22 from the INEL Site, between 25 February and 6 April, 1983.

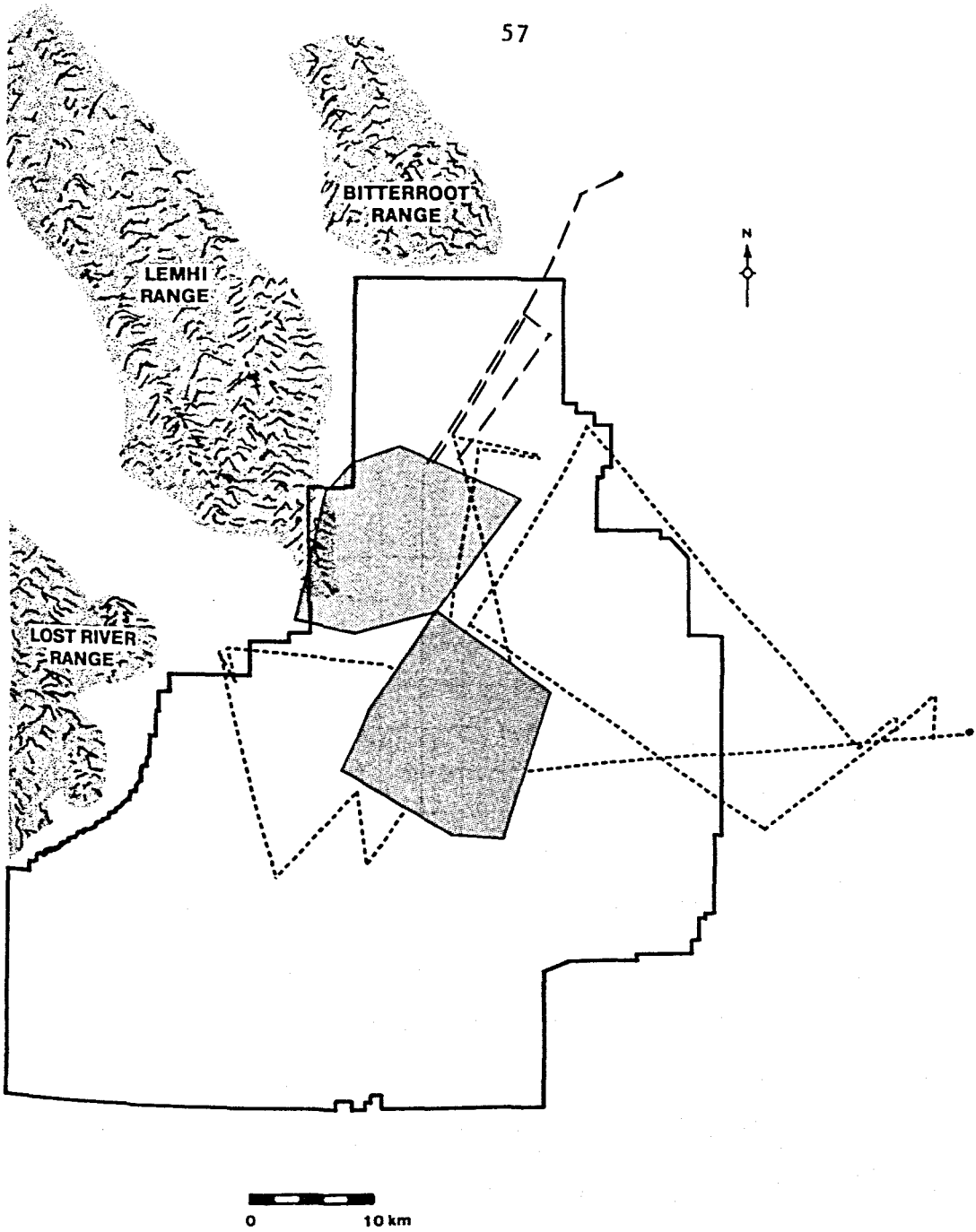

Figure 17. Premigratory movements of hawks 17 (above) and 16 (below) from seasonal ranges on the INEL Site.

range on 28 February following a snowstorm that dropped 8 cm of snow. Two 4-day movements and subsequent returns occurred on 4 and 10 March 13 km north and 33 km east, respectively. She returned to the second location in irrigated farmland 16 km southwest of Roberts, Idaho and was observed with 25 to 30 rough-legged hawks along a 2 km section of power line two days prior to migration. Hawk 17 made one movement off-range between 14 and 22 March. He moved 12 km north and was last located in this area on 9 April.

Spring Migration and Winter Range Fidelity

Hawks 16 and 20 began spring migration 14 April with partially cloudy skies and southwesterly surface winds averaging 1.5 m/sec (3.4 Miles per Hour) (Figure 18). Hawk 16 was not followed in migration but was located 32 km north of Whitehall, Montana, on 15 April. Total distance travelled was 225 km during a 31 hour period. Location with respect to surrounding mountains indicated probable migration through Monida Pass. Hawk 20 was followed two days in migration along a second corridor through Raynold's Pass. On 14 April he moved 68 km from Dubois, Idaho, and roosted near Henry's Lake, Idaho, at 1700 h. On 15 April hawk 20 perched near Ennis, Montana, at 1300 h and was last located roosting at 1700 h 13 km west of Anceney, Montana. Total distance travelled on 15 April was about 114 km.

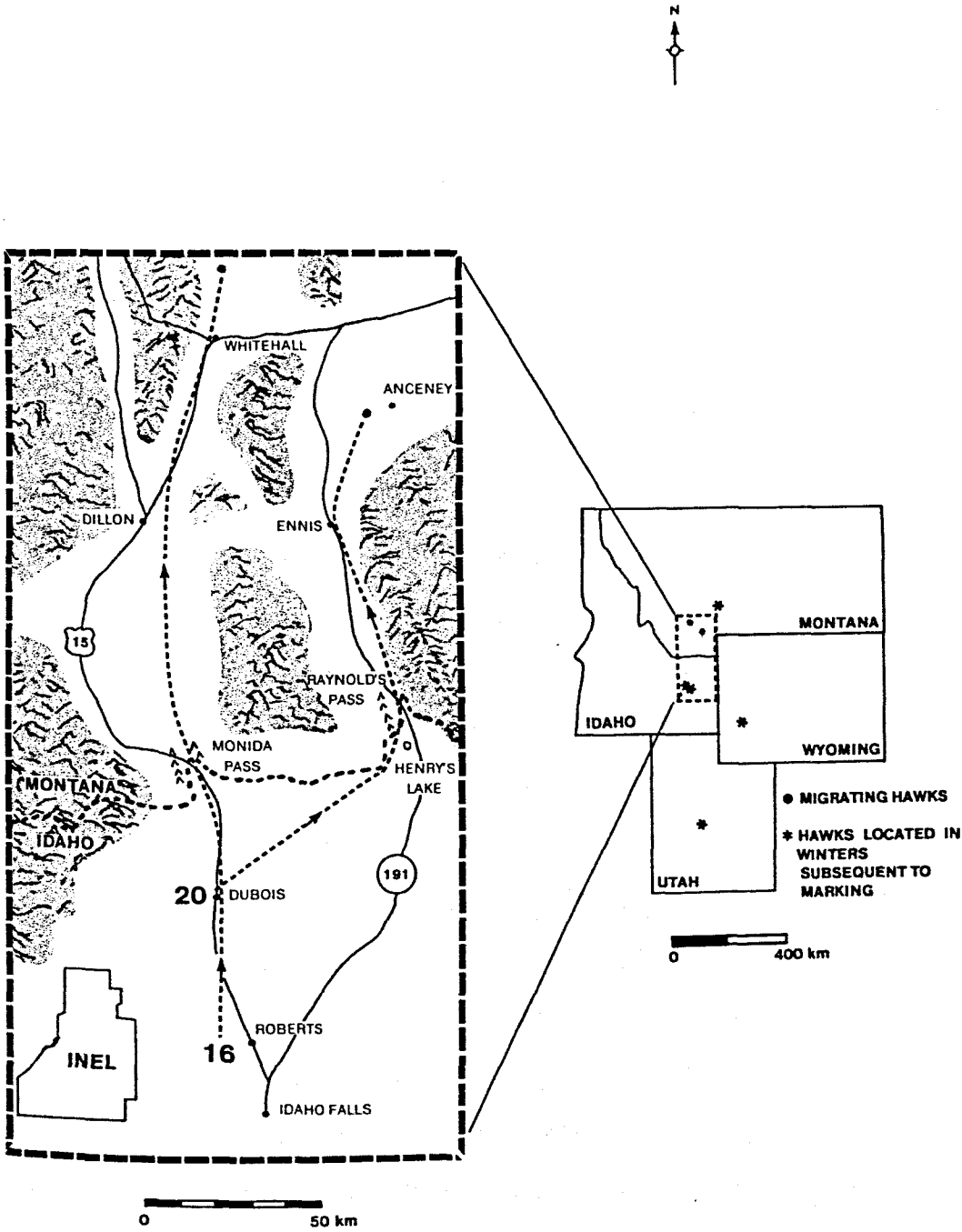

Figure 18. Probable spring migration routes of hawks 16 and 20 from southeastern Idaho (left), and marked-hawk relocations in states adjacent to Idaho (right).

Hawks 12 and 17 were last located on 9 April. Extensive aerial surveys on 14 April failed to locate either bird so they were presumed to have migrated before this date. Rough-legged hawks were last observed on the Site 19 April 1982 and 18 April 1983. Thus most rough-legged hawks migrated from this area by late April during the two winters of this study.

A few wing-marked hawks were resighted during winters following marking (Figure 18). Female 5 was seen three times over a 3-week period in February 1983 about 225 km southeast of the Site. The specific location was 5 km south of Labarge, Wyoming, on highway 189 in mixed habitat of sagebrush and hay meadows. Two unidentified orange wing-marked rough-legged hawks were observed on 20 March 1982 and 8 November 1983. The first was located 440 km south of the Site along Interstate 15 near Scipio, Utah, and the second was seen 5 km north of Wilsall, Montana, about 295 km north of the INEL Site.

At least one marked hawk returned to winter on the Site. One sighting occurred 26 November, 3 km southwest of Mudlake, Idaho, and another 23 December 1983, along highway 22, 2 km south of Birch Creek.

Food Habits

A total of 644 rough-legged hawk pellets were collected in study areas A through G during winters

1981-83 (Appendix, Tables 18 and 19). Individual food items were quantified by frequency (percent of the total number) and biomass (percent of the total weight of intact prey). Both analyses indicated a major difference in food habits of hawks inhabiting agricultural land and sagebrush-steppe habitat during combined winters (Figure 19). There was a difference in the frequency of leporids between habitat types relative to the other prey items (X^2=203.80, $p<0.001$). Leporids comprised 53.7% of prey numbers and 66.5% of prey biomass in sagebrush-steppe and only 2.2% and 7.0%, respectively, in agricultural land. There was also a difference in the frequency of montane voles found in castings between habitat types (X^2=347.80, $p<0.001$). Montane voles comprised 24.1% of prey numbers and 9.1% of prey biomass taken in sagebrush-steppe as opposed to 95.0% and 91.6%, respectively, in agricultural land. Northern pocket gophers (*Thomomys talpoides*) formed an important part of the diet in sagebrush-steppe comprising 8.2% of prey numbers and 17.7% of prey biomass for combined winters.

Overall prey diversity was greater in sagebrush-steppe than agricultural land. Nine mammalian and two avian species were identified as prey items in native vegetation while only four mammals were identified as prey in farmland. Minor shifts in prey use were observed between winters including a 7.5% reduction in

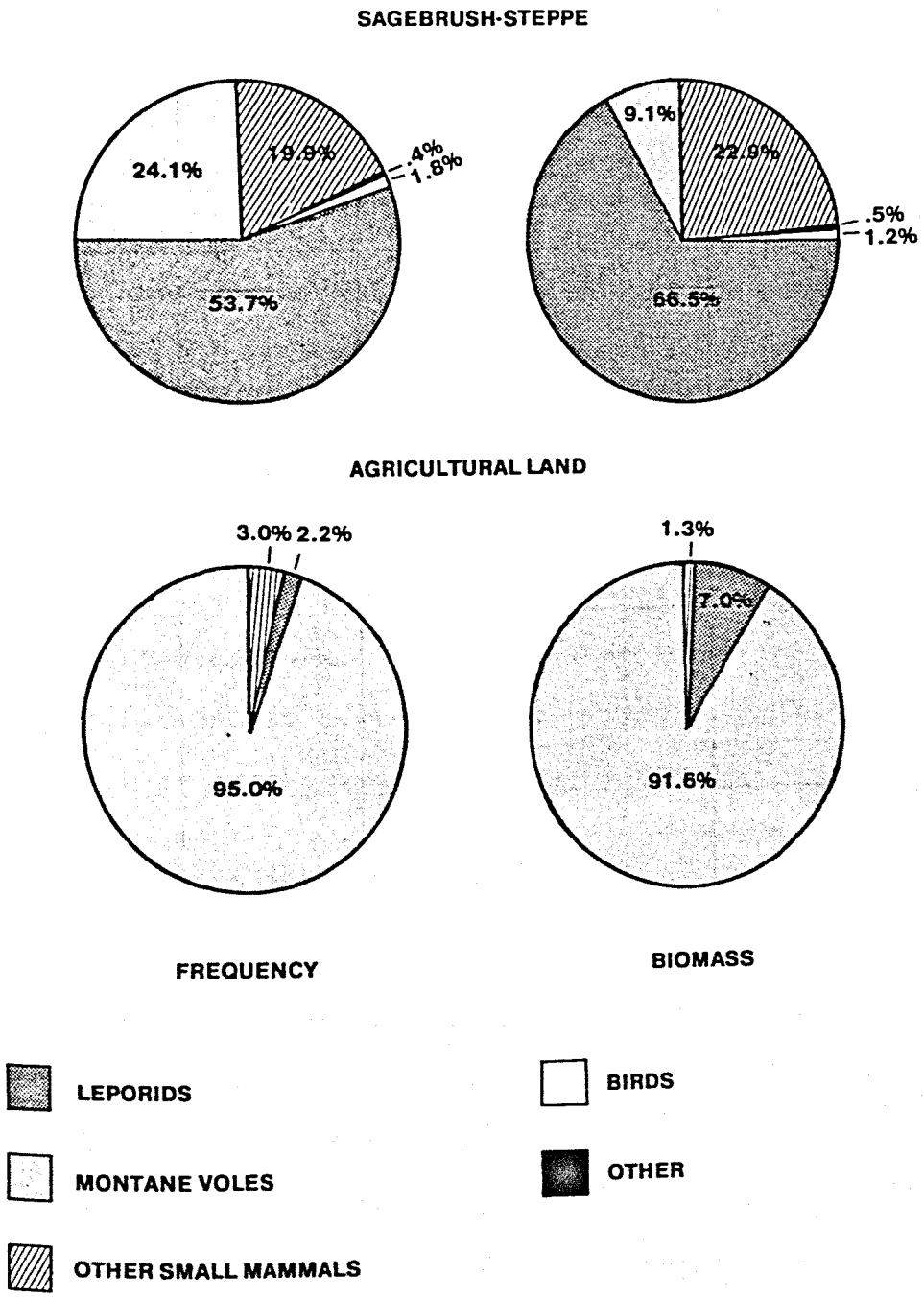

Figure 19. Prey items identified in rough-legged hawk castings during winters 1981-82 and 1982-83.

frequency of northern pocket gophers taken in sagebrush-steppe and a 3% reduction in deer mice (*Peromyscus maniculatus*) taken the second winter. These differences may reflect the reduced pellet sample size the second winter.

Small mammals were the largest prey rough-legged hawks were observed to kill. Hawks were seen in pursuit of black-tailed jack rabbits and mountain cottontails on separate occasions. Neither attempt appeared to be a serious attempt to capture prey as hawks flap-sailed about 15 m above prey without stooping. Hawks were observed to flush sage grouse and pheasants (*Phasianus colchicus*) on two different occasions. However, interactions appeared to be coincidental as hawks were in directional flight and prey was not pursued in either case.

Rough-legged Hawk Distribution Analysis

Spatial Distribution

Analysis of survey data revealed rough-legged hawks were not distributed randomly among survey sections (chi-square goodness of fit, $X^2=758.04$, $p<0.001$). Agricultural sections received greater than expected use and accounted for 91% of the chi-square value. Analysis after exclusion of agricultural sections (Neu et al. 1974) resulted in a greater use of sections 6 and 8, no

difference in use of sections 3, 4 and 7, and less use of sections 1 and 9 than expected by chance (Table 9).

Table 9. Rough-legged hawk distribution in non-agricultural sections during winter 1982-83.

Section[1]	Total km	Proportion of Section Total	Numbers of Birds Observed	Expected No. of Birds Observed	Proportion Observed Per Section	Confidence Interval on Proportion of Occurrence (90% Family Confidence Coefficient)	Significance[2]
1	24.4	0.14	24	49	0.07	0.04-0.10	S.L.
3	25.6	0.15	40	52	0.12	0.07-0.16	N.S.
4	21.4	0.13	39	45	0.11	0.10-0.13	N.S.
6	21.3	0.13	99	45	0.29	0.23-0.34	S.M.
7	18.6	0.11	37	38	0.11	0.07-0.15	N.S.
8	14.2	0.08	50	28	0.14	0.10-0.19	S.M.
9	44.8	0.26	59	91	0.14	0.12-0.22	S.L.
Total	170.3	1.00	348	348	1.01		

[1]See Table 1 for description [2]S.L.=Significantly less, N.S.=Not significant, S.M.=Significantly more

Rough-legged hawk distribution was not significantly correlated with the availability of elevated perch sites (Spearman's rank correlation r_s=0.07, p=0.865), or availability of utility poles (r_s=0.02, p=0.966) for all survey sections. There was also no correlation between rabbit carcass distribution throughout survey sections and number of hawks observed (r_s=0.23, p=0.546). Table 10 summarizes perch site and rabbit counts for survey sections.

Table 10. Perch sites and rabbit carcasses counted per kilometer along the INEL Survey route.

Parameter	Survey Section 1	2	3	4	5	6	7	8	9
Elevated perch	56	1540	12	20	296	12	25	74	35
Utility pole	3	20	3	0	10	11	22	21	11
Rabbit Carcass	1	39	6	2	13	6	7	2	10

Relative abundance of small mammals was estimated from 400 trap nights in each of study areas A through G. Townsend's ground squirrel (Spermophilus townsendi), Ord's kangaroo rat (Dipodomys ordi) and the Great Basin pocket mouse (Perognathus parvus) were excluded from calculations as these species remain inactive throughout winter and are largely unavailable to predators (T. Reynolds, pers. comm.). Deer mice comprised 99.5% (n=399) and montane voles comprised the remaining 0.5% (n=2) of trapped small mammals. A negative relationship was found between ranked relative rodent abundance and hawk numbers over all study areas (r_s=-0.76, p=0.048).

Percent total plant cover, shrub cover and grass cover were tested for correlation to hawk numbers within study areas. No relationships were determined for total plant cover (r_s=0.49, p=0.263) and percentage grass cover (r_s= -0.08, p=0.864). A negative correlation was found between percent shrub cover and hawk numbers (r_s=-0.94, p=0.002). A positive correlation was found between percent incident light on ground and relative abundance of hawks (r_s=0.96, p<0.001).

Hawk numbers, rodent indices and cover estimations for study areas A through G are summarized in Table 11.

Temporal Distribution

To analyze factors influencing changes in hawk numbers over time, total numbers of hawks observed on

each survey day were regressed on mean minimum temperature for days preceding survey and snow depth (Figure 2) and rabbit carcass count on survey day (Figure 16). Regression of hawk counts on mean minimum temperature, snow depth and rabbit count alone explained 29.9, 26.1 and 56.1% of the variability in hawk numbers, respectively. Inclusion of the three variables together decreased the explanatory power of the model (Coefficient of Determination R^2_{adj}=0.52).

Table 11. Hawk abundance, rodent indices and cover estimates in study areas.

Study Area	No. of Hawks Observed	Index of Rodent Abundance	% Total Cover	%Shrub Cover	%Grass Cover	% ground light
A	3	0.040	56.88	00.00	00.07	96.41
B	3	0.185	66.56	14.25	16.84	93.21
C	6	0.085	35.94	10.19	23.25	92.88
D	7	0.090	60.06	15.50	39.25	86.86
E	19	0.128	53.75	16.31	35.44	89.24
F	23	0.218	50.44	37.25	16.38	82.76
G	78	0.190	48.38	37.00	16.31	76.90

Due to a difference in hawk counts observed for snow depths less than and greater than 10 cm, hawk counts were also regressed on rabbit counts and a dummy variable indicating snow depths of at least 10 cm. The addition of this variable was significant (R^2_{adj}=0.65). The following was determined to be the best overall model:

$$\hat{Y} = 19.09 + 0.07x_1 + 10.98x_2$$

Where: Y = hawk count
x_1 = rabbit count
x_2 = 1 if snow depth >10 cm, 0 if <10 cm

Change in Distribution Over Time

Survey data were analyzed to see if the proportion of hawks in a given survey section changed over time. A space/time association was determined between the nine survey sections and all 18 survey days (X^2=220.21, $p<0.001$). Subdividing the chi-square analyses revealed a space/time association within the first six surveys (X^2=65.20, $p<0.010$) and no relationship after this time (X^2=106.52, $p>0.050$). Analysis of the spatial plane revealed a space/time association in sections 3 and 4 (positive residuals) and 8 (negative residuals) compared to all remaining sections which had no space/time association (X^2=100.57, $p>0.100$). Through the first six surveys more hawks were observed in sections 3 and 4 and fewer in section 8 than would have been expected. After survey 6 all sections contained the expected number of hawks on a given survey day.

Raptor Survey

Fluctuations in Counts

Twelve raptor species including the northern shrike (*Lanius excubitor*) and common raven were observed on 18 surveys during winter 1982-83 (Appendix, Table 20). Of the 4 raptor species considered residents on the Site (Craig 1978), the golden eagle was observed most frequently (0.27 birds/km), followed by the rough-legged

hawk (0.18 birds/km), the bald eagle (0.05 birds /km) and the prairie falcon (0.01 birds/km). Fluctuations in counts of these four species indicated that peak golden eagle and rough-legged hawk numbers occurred the first two weeks in January while bald eagle and prairie falcon numbers remained fairly consistent throughout winter (Figure 20).

Golden Eagle Distribution

Activities of golden eagles and rough-legged hawks at time of observation during the survey were similar in the use of utility poles as perching substrates (Table 12).

Table 12. Activities of golden eagles and rough-legged hawks during winter survey 1982-83.

Activity	Golden Eagle % of Observations	Rough-legged Hawk % of Observations
Flying	8.1(72)[1]	7.6(45)
Perched		
Ground	11.6(104)	4.6(27)
Fence	0.5(4)	3.6(21)
Tree	2.5(22)	3.0(18)
Pole	77.2(690)	74.5(441)
Sign		4.4(26)
Wire		1.5(9)
Other		0.9(5)
Total	100.1(894)	100.1(592)

[1]Number of observations

Because of the potential conflict in pole use and antagonistic encounters observed between the 2 species, golden eagle distribution was analyzed to determine preference or avoidance of survey sections and the relationship to rough-legged hawk distribution (Neu et al.

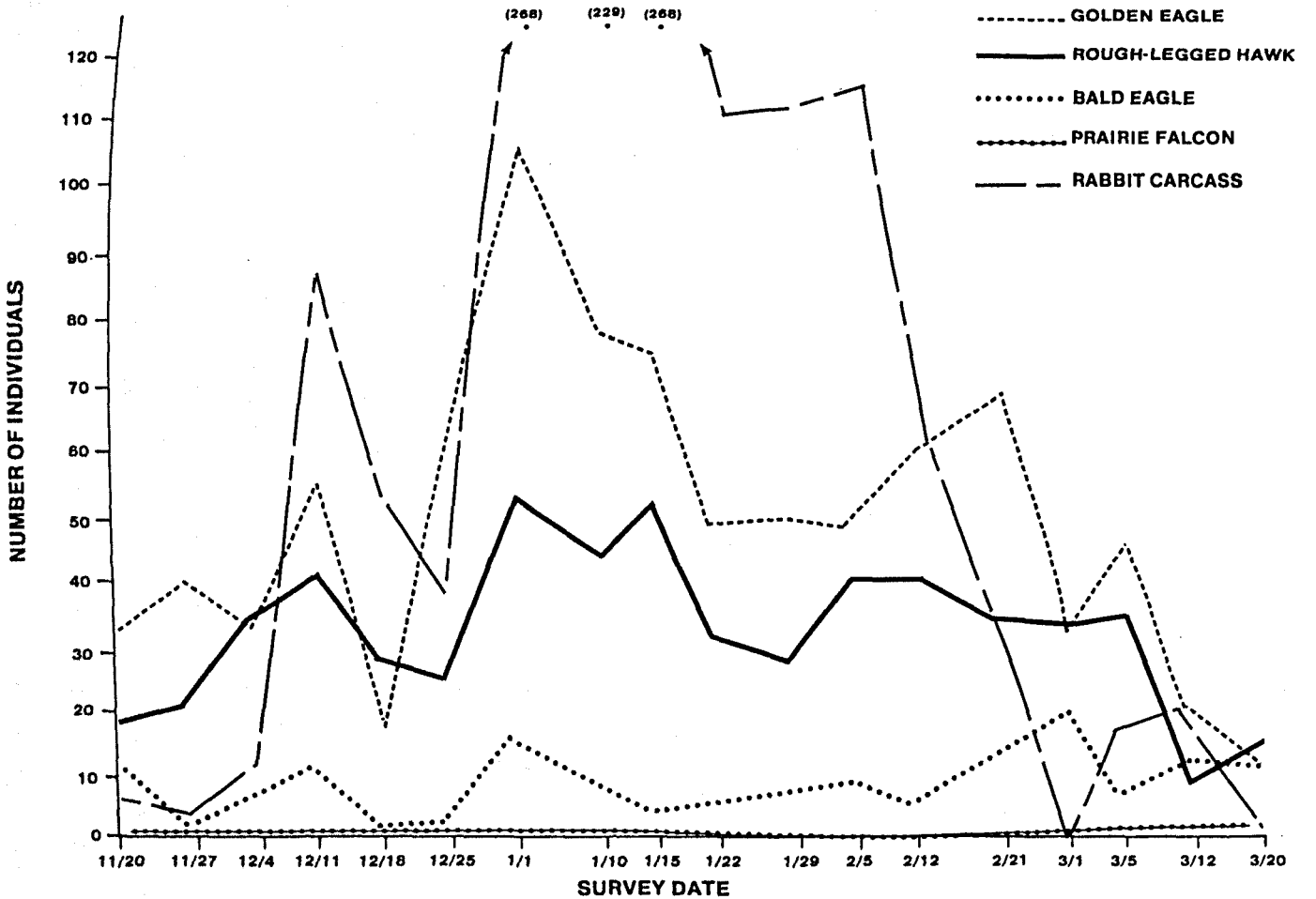

Figure 20. Raptors observed and rabbit carcasses counted on the INEL Site during the winter survey, 1982-83.

1974). More golden eagles were observed throughout winter in sections 3, 6 and 7 and fewer in sections 1, 4, 5, 8 and 9 than would have been expected if they used the sections in proportion to availability (Table 13). Golden eagle numbers were not different than expected in section 2. Thus golden eagles displayed some avoidance of agricultural land but a preference for sagebrush-grass habitat.

Table 13. Golden eagle distribution among survey sections, INEL Survey, winter 1982-83.

Section[1]	Total km	Proportion of Section Total	Numbers of Birds Observed	Expected No. of Birds Observed	Proportion Observed Per Section	Confidence Interval on Proportion of Occurrence (90% Family Confidence Coefficient)	Significance[2]
1	24.4	0.13	31	116	0.04	0.02-0.05	S.L.
2	11.6	0.06	40	54	0.05	0.03-0.06	N.S.
3	25.6	0.14	247	125	0.28	0.24-0.31	S.M.
4	21.4	0.11	35	98	0.04	0.02-0.06	S.L.
5	5.1	0.03	8	27	0.01	0.00-0.02	S.L.
6	21.3	0.11	172	98	0.19	0.18-0.21	S.M.
7	18.6	0.10	213	89	0.24	0.20-0.27	S.M.
8	14.2	0.08	45	72	0.05	0.03-0.07	S.L.
9	44.8	0.24	103	215	0.12	0.09-0.14	S.L.
Total	187.0	1.00	894	894	1.02		

[1]See Table 1 for description [2]S.L.=Significantly less, N.S.=Not significant, S.M.=Significantly more

Whereas rough-legged hawks consumed rabbit carrion, golden eagles displayed a preference for live jack rabbits. Forty-nine eagles were observed at one time hunting jack rabbits which had concentrated in a 2 km^2 field yet abundant carrion was available on a highway adjacent to this area. Eagles were also frequently observed to hunt and kill live rabbits from utility poles

when abundant carrion was available on the ground below them.

Characteristics of the Rough-legged Hawk Population

Adult hawks comprised 269 (81%) of 332 rough-legged hawks for which ages were determined throughout all surveys. Male hawks comprised 69% of the adults. No sexual segregation was observed between agricultural sections 2 and 5 and the remaining survey sections (X^2=0.00, p=0.99). In fact, exact proportions of both sexes were observed in the 2 habitat types. Only 15 (2.5%) of 592 rough-legged hawks observed winter 1982-83 were melanistic individuals.

DISCUSSION

Data from monitored individuals in conjunction with population analyses indicated that most aspects of rough-legged hawk winter ecology were a reflection of this species' opportunistic nature and were linked to the acquisition of prey. Whereas previous research has shown the influence of high microtine densities on winter buteo populations (Weller 1964, Bart 1977, Baker and Brooks 1981), this study provided insight into rough-legged hawk behavior and habitat use under conditions of relatively low vole abundance.

Two conditions which influence hawk density are prey density and prey vulnerability as result of biotic and abiotic factors (Craighead and Craighead 1956). In the present study, vegetation canopy, as a factor altering prey vulnerability, was more closely related to hawk numbers than was rodent abundance. The positive correlation of percent incident ground light to hawk numbers suggested that overhead canopy, rather than basal cover, influenced hawk distribution. Specifically, shrub cover presented a visual, and probably a physical barrier to foraging hawks. Rough-legged hawks are not finesse hunters or adept at catching agile prey. Due to its height, sagebrush would have limited hunting efficiency

with or without snow cover, which also reduced rodent vulnerability.

The efficiency of rodent capture progressively increased as cover declined from sagebrush-shrub to sagebrush-grass, grass-dominated and matted alfalfa types. Hunt success of rough-legged hawks observed in grassland or agricultural areas by Bildstein (1978), Smith (1979) and Griffen (1983) was 27.8, 26.8 and 43.2%, respectively, and greater than overall hunt success in sagebrush-steppe on the INEL Site (20.0%).

Others have found vegetative cover to influence raptor habitat use and distribution by altering hunting efficiency. Southern and Lowe (1968) found tawny owls (Strix aluco) on breeding territories captured more mice and hunted extensively in areas of less cover, although mice densities were similar in all cover types. Furthermore, two winter studies indicated that raptors, including rough-legged hawks, concentrated in habitats with less ground cover and not always in areas of highest prey densities due to increased vulnerability of prey in low cover areas (Craighead and Craighead 1956, Baker and Brooks 1981).

Results showed hawk and small mammal abundance were negatively correlated. However, indices of rodent abundance were almost entirely based on numbers of deer mice, which are largely nocturnal and therefore

unavailable to diurnal raptors (Craighead and Craighead 1956). This accounted for the low occurrence of deer mice in all analyzed castings. Trapping results indicated low vole population levels, yet voles comprised 94 and 25% of prey consumed in agriculture and sagebrush-steppe during winter 1982-83. Since castings were collected in study areas where rodent indices were developed and believed to represent general prey use in those areas, hawks may have selectively hunted voles in spite of low populations. Another possibility is that trapping techniques ineffectively assessed vole abundance, although others have found similar procedures effective in trapping voles (Craighead and Craighead 1956, Yang et al. 1970).

The differences in vole and carrion use between the two habitat types may be partially related to differences in vegetative canopy. Rough-legged hawks have been described as "microtine specialists" that can shift to other prey when voles are unavailable (White and Cade 1971). High vole and low carrion use characterized agricultural land in section 2, even though this area contained more rabbit carrion than any other survey section. This suggested that these hawks were not forced to feed on carrion but were able to locate and consume "preferred" microtines throughout winter. Hawks in the dense canopy of sagebrush-steppe however, turned to alternate prey sources such as carrion, as well as a

diverse array of mammalian and avian species. This dependence on carrion was reflected in the significant regression of hawks on carrion for all survey sections.

The affinity of rough-legged hawks for agricultural land relative to sagebrush-steppe during three previous winters on the INEL survey (Craig 1978, Craig et al. 1983), probably related to its more favorable vegetative canopy and possibly to two characteristics that make farmland more favorable for vole reproduction. First, dense and/or widely fluctuating vole populations may be more commonly associated with the high degree of forb and grass cover found on farmland, than with the lower grass cover on sagebrush-steppe habitat. Birney et al. (1976) investigated the importance of vegetative cover to Microtus in grassland habitats and postulated that a threshold of grass cover was necessary to generate cyclic population phenomena. In conditions of lesser grass cover they found population changes were too minimal to distinguish cycles. Consistently low vole populations on the INEL Site are substantiated by trapping results from previous studies. Reynolds and Trost (1980) captured three montane voles in 20,160 trap nights and Keller (1983) trapped only 11 voles during 16,423 trap nights in three years of small mammal trapping on the INEL Site.

Secondly, although vole population cycles may be synchronous for several hundred kilometers (Galushin 1974,

Krebs and Myers 1974), local populations are frequently asynchronous and susceptible to irruptions or migration as a result of flooding, freezing, burning, grazing or other forms of habitat alteration (Craighead and Craighead 1956, Birney et al. 1976). Such alterations occur frequently on agricultural land and have the potential to attract raptors. In the present study a crop rotation from barley to alfalfa in a quarter-section of agriculture resulted in an irruptive vole population the first winter. Rough-legged hawks and northern harriers hunted this field extensively. Local farmers indicated that seeded alfalfa under the cover of barley stubble provided an ideal food source and protective cover favorable for vole reproduction. The second winter when seeded alfalfa and barley cover were absent, no voles were trapped, no vole sign was noted, and no hawk concentrations were observed.

A second factor which reduced rodent availability as winter progressed was snow cover. Rough-legged hawks on sagebrush-steppe habitat responded to snow cover by increasing carrion consumption and/or moving to more suitable hunting ranges. Overall, radioed hawks exhibited a significant increase in the frequency of carrion versus rodent consumption when snow depths exceeded 12 cm. Two monitored hawks shifted weekly ranges to highways and one was observed to feed extensively on carrion in severe weather. Two others moved onto grass-dominated ranges,

possibly because of greater rodent vulnerability in this habitat type as suggested by rodent use by one bird.

Not only did hawks move locally to roads, but the significant increase in hawks observed during surveys when snow cover was above 10 cm was probably also a result of long distance movements of non-residents to ranges along the highways. The decreased proportion of hawks seen in survey sections 3 and 4 (from 5 to 0 and 10 to 0 hawks), and the simultaneous increase in section 8 beginning mid-December (from 0 to 10 hawks), suggested hawks drifted into the southern portion of the Site from distant northern ranges. The monitored movement of hawk 21 between these 2 areas in late December lent credence to this possibility. Moreover, the tendency of certain hawks to drift throughout the winter, also noted by Craighead and Craighead (1956), probably reflected the individual abilities of birds to adjust to reduced rodent availability throughout winter. Galushin (1974) explained that raptors can be nomadic to compensate for food specialization, or faithful to an area but flexible with food habits. He contended that the difference between the two strategies extended not only to the population, but to the individual level as well. Results of the present study, in circumstances of low vole and high carrion abundance, showed individual rough-legged hawks in the

same wintering population exhibited different survival strategies.

Behavioral responses of hawks to snowfall probably would have deviated from these patterns under different snow conditions and without the presence of rabbit carrion. Although hawks responded to snow cover above 10 cm, they have been observed to move to roads and scavenge carrion after as little as 2.5 (Schnell 1968) and as much as 35 cm of snow (Klein and Mason 1981), as a result of reduced rodent availability. Under other circumstances, 2.5 cm of snow precluded any small mammal use by buteos, (Baker and Brooks 1981) although a greater abundance of hawks observed when snow was 2.5 to 10 cm deep was apparently a result of patchy snow which increased rather than decreased rodent availability (Thurow et al. 1980). Thus differing snow depths, patterns of snow cover, and probably other factors such as the degree of snow crusting, may solicit different hawk responses.

Reported variability in movement of rough-legged hawks to roads and use of carrion in cold weather (Bildstein 1978, Schnell 1967a, Fleming 1981) is evidently linked to winter range character. When snow cover reduces rodent availability rough-legged hawks have the option of switching to alternate prey (if suitable prey are available), increasing use of carrion on roads, or relocating in other areas.

Behavioral shifts and movements of rough-legged hawks in response to seasonal changes in weather were directed towards energy conservation. Below 40 C, the metabolic rate-temperature function of birds is an inverse relationship (Kendeigh 1969). Thus, hawks were probably forced to increase prey intake in the severe cold of mid-winter. For example, daily dietary intake of red-tailed hawks was found to increase from 8.6 to 10.7% of the body weight in cold weather (Brown and Amadon 1968). Rough-legged hawks apparently responded by shifting to more productive hunting ranges, increasing carrion feeding and decreasing pursuit of rodents. After locating a carcass hawks could feed until they were satiated, and remain perched the remainder of the day. The overall increase in perching activities and ground perching in severe weather were characteristics of carrion feeding and resulted in shorter daily movements, smaller daily ranges and smaller mid-winter ranges relative to fall and spring.

Perching has been shown to be an energy conserving activity in raptors. Griffen (1983), for example, found that a male rough-legged hawk spent 98% of the day in non-flight activities which expended 75% of the daily energy budget. Conversely, flight activities accounted for 2% of the time yet 25% of the energy. Wakeley (1978) determined that the rate of energy expenditure of adult

ferruginous hawks while perch-hunting, soaring and in active flight was 3.5, 8.0 and 12.5 times the standard metabolic rate, or level of minimal heat production. In this context, rough-legged hawks exhibited predictable responses to cold stress.

Extensive use of utility poles as hunting substrates and a tendency towards increased hunting in evening, have been previously documented and appear to be characteristic of this species (Marion and Ryder 1975, Bildstein 1978, Sylvén 1978, Smith 1979). That hunt success from perches was greater than from hovering may be partially attributed to the fact that all strike attempts from hover flight occurred in sagebrush cover types. Thus, restrictive canopy cover may have lowered success. Griffen (1983) felt the lower capture efficiency of a male rough-legged hawk from hover flight relative to perch hunting in grassland habitat was in part related to a greater visibility of prey to predator, which may also have reduced hovering success in the present study. Low hunting success from hovering presumably resulted in a high cost/benefit ratio. Griffen (1983) determined the energy expenditure of a male rough-legged hawk per hovering bout (versus individual strike) to be 39.2 kilocalories per hour (Kcal/h), versus 5.4 Kcal/h from a still perch. This explained the lower use of hovering relative to perch-hunting in the present study.

Additionally, the association of hovering with moderate wind velocities substantiated the findings of Sylvén (1978) that this hunting technique appears energetically profitable only under conditions of suitable surface wind.

Windspeed was also an important factor determining rough-legged hawk roost sites. Greater wind velocities resulted in increased use of ground roosts and H-type utility poles and probably absence of use of abundant T-type poles as roost substrates. H-type poles allowed hawks to shield themselves behind supporting poles, whereas T-type poles offered no protection. Mosher (1976) pointed out that wind is a critical element of a bird's thermal environment, and has a severe impact on the rate of heat loss in raptors. This also explained the tendency for hawks to perch on the ground during the day under high wind velocities, a behavioral response that has been noted previously for rough-legged hawks (Bildstein 1978).

The affinity of rough-legged hawks to a particular roosting area may have resulted from their familiarity with, and thus the security these areas provided from other predators. The tendency of ground roosts to be at greater distances from roads, relative to utility poles, also implicated security from ground-dwelling predators as an important factor determining roost location.

Results showed a lack of correlation between utility pole availability and hawk distribution. Underutilization

of some areas on the INEL Site which had high numbers of utility poles indicated other factors, such as vegetation canopy and prey abundance, were more important determinants of hawk distribution. Craig (1978) arrived at the identical conclusion concerning the distribution of utility poles and rough-legged hawks on the INEL Site. However, the high number of rough-legged hawks in sections 2, 5, 6 and 8, which possessed comparatively high numbers of utility poles, suggested this habitat component did exert some influence on hawk abundance. It is noteworthy that Stahlecker (1978) found that the addition of a new transmission line altered the distribution of wintering prairie raptors.

Utility poles also exerted a noticeable influence on range characteristics of individual hawks, but again, other factors such as prey availability (Craighead and Craighead 1956, Mills 1975), and topography and vegetation (Craighead and Craighead 1956, Brown and Amadon 1968), have been noted to have equal or greater influence on the shape and extent of ranges. Winter ranges for two rough-legged hawks in areas of high vole abundance by Craighead and Craighead (1956) comprised 21% of the smallest seasonal range in the present study. This difference may largely relate to differences in prey bases and densities between studies. Hawks on a carrion-based diet probably foraged over larger areas to locate

carcasses relative to birds feeding in a high-density vole area. It is important to note, however, that ranges in Craighead's study were determined in a shorter period of time, from chance observations, and from considerably fewer relocations than those in the present study.

Social interaction did not appear to be a factor delimiting seasonal range boundaries since hawks defended perches or prey with less intensity near the outskirts of their ranges. The observed pattern of range overlap and absence of territoriality have been noted previously for rough-legged hawks (Craighead and Craighead 1956, Smith 1979), as has the defense of favorite perch sites (Craighead and Craighead 1956). Although hawks in the present study were not territorial, the distances they defended perches against intruders did appear to vary inversely with population density. Several hours of observation the first winter of study indicated that hawks in farmland defended one or two utility utility poles adjacent to their perching locations (up to 100 m away), whereas hawks in sagebrush-steppe defended perches or prey up to several hundred meters away. Resident hawks consistently exhibited a greater tolerance of one another in a high density area. Cavé (1968) noted similar behavior in wintering kestrels.

The defense of perches and prey against hawks 12 in agricultural land and 21 in the CFA may have limited their

abilities to establish ranges in occupied areas. Excessive defense against "new" hawks possibly contributed to the tendencies of some individuals to drift throughout winter. On this premise, the influx of hawks into the CFA from the north in mid-winter may have resulted in part from this area's underutilization due to its southern location, which allowed some hawks to establish ranges without social interference.

Inter and intraspecific interactions of raptors on the INEL Site suggested the existence of a social hierarchy dominated by golden eagles and followed by female rough-legged hawks, male rough-legged hawks and northern harriers. Larger sized raptors were apparently able to displace smaller birds. Bildstein (1978) concluded that the dominance of other raptors over the northern harrier was sufficient to limit the number of harriers on the study area. He also found that 88% of interspecific interactions involving prey were initiated by a larger species, and felt that the higher use of carcasses by larger raptors was due to greater success at thwarting piracies. Results on the INEL Site did not indicate that aggression influenced hawk distribution. The preference of eagles for sagebrush habitat rather than agriculture and the selection of live rabbits over carrion probably limited eagle dominance over rough-legged hawks to local displacement of individuals. Intraspecific

dominance of female hawks over male rough-legged hawks also did not result in sexual segregation between agriculture and sagebrush-steppe.

Premigratory movements of rough-legged hawks were a facet of behavior that has not been previously reported. The visual stimulus of a migrant red-tailed hawk apparently triggered the initial movement of two rough-legged hawks. The movements were generally to the north, and both hawks returned to ranges prior to migration, indicating that movements were a form of premigratory restlessness. The failure of hawks to migrate at such an early date probably signified a lack of physiological readiness for migration. Both physiological processes stimulated by changes in daylength and external behavioral stimuli are necessary for migration (Pettingill 1970).

Movements of two radioed hawks into agricultural areas with hawk concentrations may have resulted from irruptive spring populations of rodents which attracted birds. Another possibility is that these areas represented staging areas or locations where hawks gathered prior to migration. Although neither of these particular hawks was followed in migration to determine if birds migrated communally, rough-legged hawks have been observed to migrate in large numbers and loosely organized flocks (Bent 1937; Brown and Amadon 1969).

Spring migration appeared associated with the onset of mild weather, which resulted in an abrupt reduction in hawks on winter ranges. Fall migration was characterized by waves of hawks associated with the passage of weather fronts. Craig (1979) also observed the important influence of weather fronts on the number of rough-legged hawks seen on the INEL Site, although Fleming (1981) noted that weather did not appear to influence hawk distribution and migration in the Columbia Basin. The timing of spring migration of raptors has been associated with snow conditions (Brown and Amadon 1969) and changes in prey abundance (Newton 1979) but these did not appear to be important factors in the timing of rough-legged hawk migration in spring.

Fidelity of rough-legged hawks to wintering areas has been documented once (Sylvén 1978). Although certain hawks were faithful in returning to winter on the INEL Site, the wide distribution of hawks resighted in states adjacent to Idaho suggested that fidelity was not an innate behavioral response. This was not unexpected since the major prey species on the INEL Site, montane voles and black-tailed jack rabbits, are species subject to population fluctuations and low availability in certain years. Thus hawks moving through the Site would remain only if sufficient prey were available. Results did suggest that rough-legged hawks were not nomadic to the

degree of wandering indiscriminantly from breeding areas, but that they followed a general flight corridor from Canada to southwestern Montana and then passed onto winter ranges which afforded the best chance of survival.

The exact origin of hawks under study was not determined. However, two theoretical considerations suggested a possible origin. First, in terms of migratory patterns, hawks that breed furthest west tend to winter furthest west, and northernmost populations tend to winter furthest south (Newton 1979). Second, Cade (1955), found a high contrast in the degree of melanism observed in hawk populations in northwest Alaska (7%), southwest Alaska (19%), eastern Canada (12%) and western Canada (3%). Fleming (1981) speculated that hawks in the Columbia Basin migrated from northwest Alaska on the basis of similarity in the degree of melanism. The 2.5% melanism of the population on the INEL Site, and postulated migratory patterns, suggested rough-legged hawks in southeastern Idaho migrated from western Canada.

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APPENDIX

Table 14. Trapped and road-killed rough-legged hawks on the INEL Site from January 1982 to February 1983.

Date	Trapped or Road-killed	Band #	Marker #	Sex & Age[1]	Wing Chord (mm)	Culmen Length (mm)[2]	Tarsus Width (mm)	Weight (g)	Location
1/12/82	T	98749746	F01	F-SY	--	32.9	10.0	1175	43°45'N 112°45'W
1/15/82	T	98749747	F02	F-ASY	--	32.3	8.8	1125	43°45'N 112°45'W
1/20/82	T	98749748	F03	M-SY	--	30.8	6.7	925	43°45'N 112°45'W
1/22/82	T	98749749	F04	F-ASY	--	31.5	9.2	1275	43°45'N 112°45'W
2/1/82	T	98749750	F05	F-ASY	--	31.0	8.5	975	43°30'N 113°W
2/1/82	T	98749751	F06	M-ASY	--	27.5	7.1	1000	43°45'N 112°45'W
2/2/82	R	--	--	F-SY	--	32.1	9.3	1250	--
2/2/82	R	--	--	F-ASY	442	29.8	8.7	975	--
2/2/82	T	98749752	F07	M-ASY	--	29.3	7.2	975	43°30'N 113°W
2/6/82	R	--	--	M-ASY	--	27.1	7.7	1050	--
2/16/82	R	--	--	F-SY	440	31.2	8.3	1450	--
2/16/82	R	--	--	M-ASY	400	29.8	7.2	--	--
2/17/82	R	--	--	M-ASY	--	30.7	7.3	--	--
3/24/82	R	--	--	M-ASY	400	28.3	8.0	1200	--
4/9/82	[3]	--	--	F-ASY	425	32.5	8.1	1250	--
10/22/82	T	98749753	F08	F-ASY	435	32.0	9.0	1050	43°45'N 112°45'W
10/22/82	T	98749754	F09	M-ASY	410	26.0	7.0	865	43°45'N 112°45'W
10/23/82	T	98749755	F10	F-ASY	440	31.0	9.3	1070	43°45'N 112°45'W
10/28/82	T	98749756	F11	F-ASY	445	35.5	8.0	1370	43°45'N 112°45'W
10/29/82	T	98749757	F12	M-ASY	415	29.3	7.5	840	43°45'N 112°45'W
10/30/82	T	98749758	F13	F-ASY	445	38.0	8.8	1155	43°45'N 112°45'W
11/4/82	R	--	--	M-ASY	402	30.0	7.5	890	--
11/9/82	T	98749759	F14	M-ASY	412	30.0	7.3	955	43°45'N 112°45'W
11/12/82	T	98749760	F15	F-ASY	440	29.8	8.2	1070	43°30'N 113°W
11/20/82	T	98761354	F16	F-ASY	423	29.5	7.5	1190	43°45'N 112°45'W
12/7/82	T	98761351	F17	M-ASY	400	27.5	7.5	890	43°45'N 112°45'W
12/11/82	R	--	--	M-ASY	420	27.5	6.5	950	--
12/11/82	R	--	--	F-FY	435	31.6	8.6	1330	--
12/11/82	R	--	--	F-FY	435	30.1	8.5	1175	--
12/14/82	R	--	--	F-ASY	440	30.5	8.2	1120	--
12/15/82	T	98761352	F18	M-ASY	415	29.2	8.4	850	43°45'N 112°45'W
12/22/82	T	98761353	F21	F-ASY	420	29.5	8.5	990	43°45'N 112°45'W
12/30/82	R	--	--	M-ASY	416	27.1	7.7	1110	--
1/4/83	T	98761355	F20	M-ASY	400	29.5	7.2	920	43°45'N 112°45'W
1/20/83	T	98761356	F22	M-ASY	412	30.7	8.1	910	43°30'N 113°W
1/21/83	T	98761357	F23	M-ASY	410	29.6	8.0	1090	43°30'N 113°W
2/5/83	R	--	--	F-ASY	444	31.1	9.0	1270	--

[1] M=Male, F=Female, FY=First Year, SY=Second Year, ASY=After Second Year [2] Includes Cere [3] Electrocuted

Table 15. Sexual differences in body characteristics of trapped and road-killed rough-legged hawks on the INEL Site.

Sex	Wing Chord (mm)	Culmen Length (mm)	Tarsus Width (mm)	Weight (g)
Female	436.4±8.2[1] (14)[2]	31.7±2.1 (19)	8.7±0.6 (19)	1171.8±134.5 (19)
Male	408.6±7.3 (13)	28.9±1.5 (18)	7.4±0.5 (18)	963.8±102.5 (16)

[1]Standard deviation [2]Sample size

Table 16. Data relating to ranges of radioed hawks 22 and 23, and wing-marked hawks 4, 14 and 18. All hawks were adults.

Hawk	Inclusive Dates of Observation	No. of Days	No. of Locations	Area (km^2)	Standard Diameter (km)	Sex
4	1/22/82-2/23/82	31	31	3.4	1.6	F
14	11/9/82-4/1/83	143	48	27.9	6.0	M
18	12/15/82-12/29/82	14	36	8.2	2.5	M
22	1/20/83-2/25/83	36	336[2]	116.5	7.7	M
23	1/21/83-3/9/83[1]	47	390	23.3	1.7	M

[1]Lost radio 3/10 [2]Excludes premigratory movements

Table 17. Daily roost to roost movements of rough-legged hawks on the INEL Site during winter 1982-83.

Date	Hawk	No. Locations	Total Distance Moved (km)	Area (km^2)	Maximum Distance Moved Between Locations(km)	Mean Distance Moved (km±S.D.)
11/2/82	13	12	19.6	19.6	4.3	1.8 ±1.5
11/3/83	13	10	9.6	2.5	2.3	1.1 ±0.8
11/4/82	13	10	23.9	19.6	7.9	2.7 ±2.5
11/5/82	13	12	14.1	5.9	5.1	1.3 ±1.6
11/11/82	13	13	29.2	22.8	7.6	2.4 ±2.5
11/16/82	15	51	9.5	2.2	1.4	0.2 ±0.2
12/8/82	17	8	7.8	6.5	3.0	1.1 ±1.2
12/9/82	17	9	9.5	11.7	2.6	1.2 ±1.1
12/15/82	17	8	6.9	2.2	1.8	1.0 ±0.6
1/12/83	17	6	4.5	1.0	2.1	0.9 ±0.9
1/13/83	17	16	10.2	1.6	3.1	0.7 ±0.8
1/14/83	17	12	6.4	1.2	2.7	0.6 ±0.8
1/14/83	21	13	16.6	13.5	4.2	1.4 ±1.4
1/17/83	21	10	13.1	6.5	2.7	1.5 ±0.8
1/17/83	12	15	16.2	6.4	2.4	1.2 ±0.8
1/18/83	12	12	6.1	1.8	1.9	0.6 ±0.7
1/18/83	21	8	2.9	0.6	1.4	0.4 ±0.5
1/25/83	23	13	10.2	3.1	3.3	0.9 ±0.9
1/26/83	23	12	17.1	7.7	4.6	1.6 ±1.9
1/27/83	23	26	12.0	4.4	1.7	0.5 ±0.4
1/28/83	23	14	14.3	4.8	4.1	1.1 ±1.3
2/1/83	17	7	19.7	20.2	7.7	3.3 ±3.1
2/4/83	12	25	11.5	2.1	1.7	0.5 ±0.5
2/4/83	23	9	4.2	0.6	1.0	0.5 ±0.3
2/8/83	12	12	5.5	1.4	1.4	0.5 ±0.5
2/10/83	23	55	10.9	1.2	1.2	0.2 ±0.2
2/11/83	23	14	8.8	1.1	1.6	0.7 ±0.5
2/14/83	23	17	10.2	2.4	2.4	0.6 ±0.6
2/16/83	22	12	8.7	7.7	2.8	0.8 ±1.0
2/17/83	23	20	5.1	0.4	0.9	0.3 ±0.2
2/18/83	22	78	33.1	10.9	6.1	0.4 ±1.0
2/18/83	23	13	5.0	0.5	1.4	0.4 ±0.4
2/22/83	12	19	16.7	17.8	7.7	0.9 ±1.9
2/22/83	23	27	9.6	0.7	1.2	0.4 ±0.3
2/23/83	22	68	33.5	25.4	5.5	0.5 ±0.9
2/23/83	23	32	13.6	1.6	1.2	0.4 ±0.3
2/24/83	12	18	6.6	2.3	2.9	0.4 ±0.7
2/24/83	23	29	9.5	1.4	1.6	0.3 ±0.5
2/25/83	22	42	18.9	11.9	4.1	0.5 ±0.8
2/25/83	12	7	6.1	3.8	3.0	1.0 ±1.3
2/25/83	16	17	23.7	15.1	17.4	1.5 ±4.3
3/2/83	12	28	33.5	33.7	12.3	1.3 ±3.0
3/2/83	22	43	21.4	6.2	3.2	0.5 ±0.7
3/3/83	12	26	19.3	12.9	5.9	0.8 ±1.4
3/4/83	16	16	20.4	25.1	9.6	1.4 ±2.7
3/4/83	23	22	12.0	2.1	1.9	0.6 ±0.6
3/9/83	12	10	37.5	48.6	9.7	4.2 ±3.5

Table 18. Prey items identified in rough-legged hawk castings collected on the INEL Site.

Prey Item	Winter 1981-82 (338 pellets)			Winter 1982-83 (109 pellets)			Combined Winters (447 pellets)		
	% of Individuals	Biomass (g)	% Biomass	% of Individuals	Biomass (g)	% Biomass	% of Individuals	Biomass (g)	% Biomass
Montane Vole (*Microtus montanus*)	23.7 (88)	3080	8.9	25.2 (29)	1015	9.6	24.1 (117)	4095	9.1
Deer Mouse (*Peromyscus maniculatus*)	6.2 (23)	333	1.0	1.7 (2)	28	0.3	5.1 (25)	361	0.8
Least Chipmunk (*Eutamias minimus*)	1.4 (5)	160	0.5	—	—	—	1.0 (5)	160	0.4
Northern Pocket Gopher (*Thomomys talpoides*)	10.0 (37)	7400	21.4	2.6 (3)	600[1]	5.7	8.2 (40)	8000	17.7
Townsend Ground Squirrel (*Spermophilus townsendi*)	1.9 (7)	994	2.9	1.7 (2)	284	2.7	1.9 (9)	1278	2.8
Northern Grasshopper Mouse (*Onychomys leucogaster*)	0.8 (3)	78	0.2	—	—	—	0.6 (3)	78	0.2
Sagebrush Vole (*Lagurus curtatus*)	—	—	—	0.9 (1)	30	0.3	0.2 (1)	30	0.1
Unindentified Small Mammals	3.2 (12)	360	1.0	1.7 (2)	60	0.6	2.9 (14)	420	0.9
Black-tailed Jack Rabbit (*Lepus californicus*)	22.4 (83)	9545	27.6	35.7 (41)	4715	44.5	25.5 (124)	14260	31.6
Unidentifed Leporids	28.8 (107)	12305	35.6	26.1 (30)	3450	32.6	28.2 (137)	15755	34.9
Pronghorn Antelope (*Antilocapra americana*)	—	—	—	1.7 (2)	230	2.2	0.4 (2)	230	0.5
Sage Grouse (*Centrocercus urophasianus*)	0.3 (1)	115	0.3	0.9 (1)	115	1.1	0.4 (2)	230	0.5
Horned Lark (*Eremophila alpestris*)	—	—	—	0.9 (1)	21	0.2	0.2 (1)	21	0.1
Unidentified Passerines	1.4 (5)	210	0.6	0.9 (1)	42	0.4	1.2 (6)	252	0.6
Total	100.1 (371)	34580	100.0	100.0 (115)	10590	100.2	99.9 (486)	45170	100.2

[1]Biomass estimate based on weight of Townsend pocket gopher (*Thomomys townsendi*)

Table 19. Prey items identified in rough-legged hawk castings collected on agricultural land near Howe, Idaho.

Prey Item	Winter 1981-82 (165 pellets)			Winter 1982-83 (32 pellets)			Combined Winters (197 pellets)		
	% of Individuals	Biomass (g)	% Biomass	% of Individuals	Biomass (g)	% Biomass	% of Individuals	Biomass (g)	% Biomass
Montane Vole (*Microtus montanus*)	95.0 (224)	7840	93.0	94.0 (33)	1155	83.4	95.0 (257)	8995	91.6
Deer Mouse (*Peromyscus maniculatus*)	3.0 (7)	101	1.2	—	—	—	2.6 (7)	101	1.0
Least Chipmunk (*Eutamias minimus*)	0.4 (1)	32	0.4	—	—	—	0.4 (1)	32	0.3
Black-tailed Jack Rabbit (*Lepus californicus*)	1.7 (4)	460	5.5	—	—	—	1.5 (4)	460	4.7
Unidentified Leporids	—	—	—	6.0 (2)	230	16.6	0.7 (2)	230	2.3
Total	100.1 (236)	8433	100.1	100.0 (35)	1385	100.0	100.2 (271)	9818	99.9

Table 20. Raptors observed during winter survey 1982-83 on the INEL Site.

Species	Survey Date																		Total	Birds/km
	11/20	11/27	12/4	12/11	12/18	12/25	1/1	1/10	1/15	1/22	1/29	2/5	2/12	2/21	3/1	3/5	3/12	3/20		
Prairie Falcon (*Falco mexicanus*)	2	1		2			2	1	1					1	2	2	2	1	17	0.010
American Kestrel (*Falco sparverius*)	1	1							1										3	0.001
Northern Harrier (*Circus cyaneus*)	2			3	1	1			1										8	0.002
Northern Shrike (*Lanius excubitor*)	2		1					1		1			1	1					7	0.002
Common Raven (*Corvus corax*)	1	2	3				5		3	1	7	5	8	1	8	9	1		54	0.020
Ferruginous Hawk (*Buteo regalis*)			1	2			2	1			1	1			1	2	5	7	23	0.010
Red-tailed Hawk (*Buteo jamaicensis*)															1		1	2	4	0.001
Rough-legged Hawk (*Buteo lagopus*)	19	22	35	42	28	25	53	45	52	31	29	42	42	35	34	35	9	14	592	0.180
Unidentified Buteo								1				1			1			4	7	0.002
Golden Eagle (*Aquila chrysaetos*)	33	40	33	55	17	57	108	78	76	49	50	49	62	70	33	47	20	17	894	0.270
Bald Eagle (*Haliaeetus leucophalus*)	12	2	7	10	1	4	15	9	4	6	7	10	6	14	20	7	13	11	158	0.050
Unidentified Eagle		1	3			2		2				1	1			2	1		13	0.004