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DIET AND HABITAT USE OF NESTING PRAIRIE FALCONS (FALCO MEXICANUS) IN AN AGRICULTURAL LANDSCAPE IN SOUTHERN ALBERTA

BY

LAURIE EMILY HUNT

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

IN

DEPARTMENT OF FOREST SCIENCE

EDMONTON, ALBERTA

FALL, 1993

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Laurie E Hunt

Laurie E. Hunt
Department of Forest Science
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April 30, 1993

He clasps the crag with crooked hands,
Close to the sun in lonely lands,
Ring's with the azure world, he stands.

The wrinkled sea beneath him crawls,
He watches from his mountain walls,
And like a thunderbolt he falls.

---Tennyson

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled DIET AND HABITAT USE OF NESTING PRAIRIE FALCONS (FALCO MEXICANUS) IN AN AGRICULTURAL LANDSCAPE IN SOUTHERN ALBERTA submitted by LAURIE EMILY HUNT in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

Geoffrey L. Holroyd

James R. Butler

Susan Hannon

Ellen Macdonald

APRIL 23, 1993

ABSTRACT

I studied diet and feeding behaviour of 8 pairs of nesting Prairie Falcons (Falco mexicanus) in southern Alberta in 1989 and 1990. I identified prey by direct observation of prey delivered to the nest site, and by examination of prey remains from perch sites and pellets. Comparison of species composition derived using the two techniques demonstrated that collections of pellet and prey remains misrepresented the percent frequency and percent biomass of Richardson's Ground Squirrel (Spermophilus richarsonii) and birds in the diet. Using direct observation I determined that Richardson's Ground Squirrels accounted for 68 % of all delivered prey items (n=250 items). I analyzed prey remains and pellets to identify the species of birds and small mammals in the diet. Birds, primarily Western Meadowlark (Sturnella neglecta), European Starling (Sturnus vulgaris), and Horned Lark (Eremophila alpestris), comprised 27% of the diet. The remaining 5% of the diet consisted of small mammals. Male falcons delivered 71%, 71% and 57% of prey during incubation, nestling and fledgling stages, respectively. Primary prey of male falcons switched from Richardson's Ground Squirrels to birds in June. This change corresponded in time with the doubling of prey delivery rates of female falcons. Female falcons delivered primarily ground squirrels throughout the nesting cycle.

I used radio telemetry to determine home ranges, foraging ranges, and core areas used within foraging ranges of Prairie Falcons during the breeding season. Using a Landsat Thematic Mapper (TM) image and SPANS Geographic Information System (GIS), the study area was divided into five habitat types: native range 1, native range 2, irrigated crops, other crops, and water. Prairie Falcon home ranges had significantly higher proportions of native range 1, than expected based on availability within a 15 km radius area around each nest site. Almost all patches of native range 1 contained Richardson's Ground Squirrel colonies, while patches of native range 2 did not. Core areas used when ground squirrel prey was delivered exhibited higher proportions of native range 1 and lower proportions of irrigated crop than expected based on availability. Mean maximum distance (km) and size (ha) of foraging trips when ground squirrel prey were delivered were greater than for foraging trips when bird prey were delivered. Home ranges, foraging ranges and core foraging areas overlapped between adjacent pairs of nesting falcons and within pairs.

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I am especially grateful to Geoff Holroyd for his extended support, integrity, and advice concerning this study. Thanks to G. Holroyd, S Hannon, Dan Farr, John Nishi, and Navjot Sodhi for reviewing my thesis.

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This study was funded by Recreation, Parks, and Wildlife Foundation (RPW), S.T.E.P., Canadian Wildlife Service, North American Waterfowl Management Plan, and The University of Alberta.

PROTECTION OF NEST SITE INFORMATION

To protect nest sites of Prairie Falcons in southern Alberta, the text and maps in this report give no information that might lead anyone to a nest site. Information about falcon nesting sites, needed for any legitimate purpose, may be obtained from the Canadian Wildlife Service, Room 210, 4999-98 Ave, Edmonton, AB., Canada, T6B 2X3.

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1.0 INTRODUCTION

The Prairie Falcon (Falco mexicanus) is a large falcon inhabiting dry open areas in the western United States, southern Canada, and northern Mexico. Its breeding range extends from central British Columbia, southern Alberta, southern Saskatchewan, and North Dakota south to Baja California, southern Arizona, southern New Mexico, and northern Texas (Brown and Amadon 1968, Godfrey 1970, American Ornithologists Union 1983). Its range reaches the Pacific Ocean south of San Francisco Bay, but it is otherwise an interior species (Beebe 1974). Although the Prairie Falcon is migratory, reaching central Mexico in the winter, small numbers of birds winter in southern British Columbia, Alberta, Saskatchewan, and more rarely, Manitoba (Brown and Amadon 1968, Godfrey 1970, A.O.U. 1983).

In Alberta, Prairie Falcons breed primarily in badlands and river coulees along the Bow, Red Deer, Milk, South Saskatchewan, and Oldman Rivers and tributaries. Prairie Falcons return to their nesting sites in late winter to early spring to establish territories during the nesting season (Newton and Marquiss 1983). Territories may include a cliff, a portion of a cliff, or a series of cliffs with one or more nest sites used in different years. Nests are built on cliff ledges, in potholes or larger caves, or in old cliff nests of eagles, ravens or Ferruginous Hawks (Buteo regalis) (Enderson 1964, Edwards 1973, Ogden 1973, Beebe 1974), and are typically associated with open, treeless terrain which accommodates their low altitude style of hunting. Prairie Falcon utilize a wide variety of foods, including mammals, birds, reptiles, and insects. During the breeding season, the primary food source is ground squirrels (Ogden 1973, U.S.D.I. 1979). Little is known about the food habits of post-breeding populations of Prairie Falcon. Wintering birds in the United States, appear to depend heavily on Horned Larks (Eremophila alpestris) (Enderson 1964, White and Roseneau 1970, Garrett and Mitchell 1973).

In the past, the Prairie Falcon has been considered an endangered species in Canada because of its restricted range (Godfrey 1970). From 1959 to 1969, Fyfe and Armbruster (1977) recorded a 34% reduction in the occupancy of territories in Alberta and Saskatchewan. Further studies showed a correlation between the use of organochlorine pesticides and Prairie Falcon declines (Fyfe et al. 1969). Based on this and other evidence, several Canadian

government agencies cooperated to reduce the amounts of these pesticides being used. In 1977, Fyfe reported that Prairie Falcons populations were stable in Canada. The rapid conversion of grazing land to agriculture in the last decade, however, may presently be posing a serious threat to Prairie Falcon populations. In 1988, the Prairie Falcon was listed in the Prairie Conservation Action Plan as a species of concern (WWF 1988).

Although it is difficult to determine the effects of land-use changes on Prairie Falcon populations, loss of suitable hunting habitat is probably the most important factor threatening present populations. Garrett and Mitchell (1973) reported that small mammal control programs in San Joaquin Valley, California, have reduced mammalian prey species and appear to have reduced nesting densities of Prairie Falcons. The remaining population preys primarily on small passerines. In areas where Prairie Falcon feed primarily on birds, productivity and nest success are much lower than where the diet is primarily mammalian (U.S.D.I. 1979).

From 1973 to present, surveys of Prairie Falcon in southern Alberta have been conducted by the Canadian Wildlife Service and Alberta Fish and Wildlife. Objectives of these surveys were to locate new Prairie Falcon nesting sites, and to document the occupancy of nest sites over a number of years. Surveys from 1974 to 1989, show a decreasing trend in the number of pairs of occupied nest sites along a 30 km stretch of the Bow River in southern Alberta (unpubl. data). The availability of vacant nest sites along with small nesting territories, suggests that factors, other than shortage of nest sites, must be affecting the density of nesting populations of Prairie Falcon.

From 1970 to 1983, the number of acres under irrigation within the Bow River and Eastern Irrigation districts increased substantially from 23,783 to 190,262 and 199,729 to 249,372, respectively (Alberta Agriculture 1987). From 1970's to 1985, the area of cultivated land surrounding 39 documented nest sites (36 sq.km.) increased significantly (unpubl. data). Rapid conversion of native grazing land to cultivated agricultural land may be posing a serious threat to Prairie Falcons. Studies in Idaho showed that poisoning, extensive use of farm machinery, and elimination of habitat caused a decline in ground squirrel populations, and falcon hunting habitat (U.S.D.I 1979). Loss of suitable hunting habitat, due to the conversion of prairie to cultivated land, is probably the most important factor threatening present Prairie Falcon populations.

Little is known about diet or habitat use of Prairie Falcons

nesting in Canada, where land use patterns and prey species may differ from those farther south. These and other differences, make it difficult to base land use and wildlife management decisions on studies from the U.S.A. This study will determine the diet, foraging patterns and habitat use of a population of Prairie Falcons nesting along the Bow River in southern Alberta. A better understanding of the ecological factors affecting nesting falcons will be a useful tool for wildlife managers and land owners in Alberta.

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2.0 SEXUAL DIFFERENCES IN DIET AND FEEDING BEHAVIOUR OF PRAIRIE FALCONS (FALCO MEXICANUS) THROUGHOUT THE NESTING CYCLE, IN SOUTHERN ALBERTA, CANADA

2.1 INTRODUCTION

In Canada, more than 80% of the native prairie landscape has been transformed by agriculture, urbanization and industrialization (World Wildlife Fund Canada 1988). Prairie Falcons (Falco mexicanus), near the top of their food chain, are viewed as indicators of environmental quality due to rapid and apparent changes in density, productivity, and foraging strategies following habitat loss or degradation (Newton 1979). Studies in Idaho showed that poisoning, extensive use of farm machinery, and elimination of habitat caused a decline in prey populations and falcon hunting habitat (U.S.D.I. 1979). In the United States, small mammals and birds dominate the diet of Prairie Falcons, with specific prey frequencies varying regionally (Haak 1982, Sitter 1983, Boyce 1985, Holthuijzen et al. 1987, Steenhof and Kochert 1988, Anderson and Rongstad 1989, Squires et al. 1989, Holthuijzen 1990). However, in Canada where prey species composition and land use practices differ from those further south, data on diet includes only occasional foraging observations and isolated notes of food remains at nest sites (Edwards 1973, Fyfe and Armbruster 1977). To ensure that adequate habitat for nesting Prairie Falcons and their prey species is retained in Canada, land managers need first to determine the diet of nesting Prairie Falcons.

Direct observation of prey delivery to the nest site is regarded as the best indicator of diet because it represents an accurate account of what is brought to the nest (Marti 1987, Holthuijzen 1990). However, most research on the food habits of raptors has depended on periodic sampling of prey remains and pellets at nest sites to determine the diet (Fowler 1931, Bond 1936a, Craighead and Craighead 1956, Enderson 1964, Ogden 1973, Porter and White 1973, Smith and Murphy 1973, MacLaren et al. 1988, Sodhi and Oliphant 1993). Recently, Collopy (1983) and Simmons et al. (1991) demonstrated that by combining data from pellets and prey remains an accurate assessment of diet can be achieved for eagles and harriers, respectively. However, no study has compared the accuracy of species composition estimates derived from collections of pellet

and prey remains and those based on observed prey deliveries for Prairie Falcons.

In the United States, the parental care and feeding habits of adult Prairie Falcons have been documented throughout the nesting cycle (Haak 1982, Sitter 1983, Holthuijzen 1990,). Differences in prey delivery rates were found among years, stages of the nesting cycle, nesting pairs, and between the sexes (Holthuijzen 1990). In Canada, no studies have been done for comparison of patterns of parental care by male and female falcons.

My goal was to record diet and feeding behaviour of Prairie Falcons nesting in an agricultural landscape on the Canadian prairies. My objectives were to (1) identify prey items, (2) compare direct observation versus examination of prey remains and pellets as 2 different methods of diet determination, and (3) observe feeding behaviour of parents through the nesting cycle.

2.2 METHODS

Study Area

The Bow River Study Area (B.R.S.A.), encompassing approximately 7,500 km^2 and a 120 km stretch of the Bow River in southern Alberta, is characterized by badlands, river coulees, grazing reserves, and intensive agriculture. The study area is located within the Short Grass Ecoregion (Strong and Leggat 1992). Sand and clay cliffs up to 40 m high, with occasional benches and buttes, border the river and provide numerous nesting and roosting sites for Prairie Falcons (unpubl. data).

A 1989 landsat image and a geographic information system (GIS) were used to classify the study area into seven habitat types: native range 1 (2.9%), native range 2 (42.5%), tame rangeland (11.2%), bare ground (4.2%), dryland crop (7.2%), irrigated crop (28.1%), and water (3.7%) (Usher 1993; see Chapter 3.0). Crop production includes sugarbeets, alfalfa, vegetables, corn, wheat, oats, and barley.

Observation of Nest Sites to Determine Diet and Behaviour

Ledges used by breeding falcons were found during ground searches and river surveys in early May, 1989-90. Observations at nest sites started during the first week in May, 1 or 2 weeks prior to hatching, and continued until the young fledged or the nesting attempt failed. Four breeding pairs were observed each year. Sites were selected for study based on their proximity to cultivated or

uncultivated lands. In both years, I selected 2 nest sites adjacent to cultivated land and 2 nest sites adjacent to uncultivated land for comparison. The majority of observation periods were 4 to 6 hours long and occurred either before 1200 hrs or between 1600 and 2200 hrs. Each site was usually observed every second day, rotating between morning and evening observation periods. An observer (1-6), equipped with a 15-60X spotting scope, and 7 x 35 to 10 x 50 binoculars, was positioned across the river from the nest to provide optimum visibility of the site with little disturbance to the nesting birds. The observer focused on one pair of birds, and recorded the behaviour of both male and female birds. The observers were rotated between nest sites to minimize observer bias. Adult falcons were fitted with radio transmitters in May which aided in identification of individuals. Adult falcons were trapped at nest sites using noose carpets, and were fitted with 216-mHz radio transmitters using a tail mount (15 g) or backpack harness of teflon tubing (18 g). Tail mounts were attached to the rachis of two central tail feathers with dental floss and crazy glue. Tail mounts were molted with the tail feathers in late July, at approximately the same time that young fledged and adults dispersed.

Sex of the focal bird was determined by relative size (Palmer 1988), sex specific behaviour (e.g., food begging, incubating), and directional location of radio transmitter signals. The frequency of food delivery to the nest and identification of individual prey items were made by direct observation. I defined food delivery as any time prey was delivered to the nest. Some prey items may have accounted for more than one feeding visit if they were partially eaten, cached, and then brought back to the scrape and fed to the young (Sitter 1983). Prey was classified as Richardson's Ground Squirrel (Spermophilus richarsonii), unidentified small mammal, or unidentified bird. Biomass of Richardson's Ground Squirrels in the diet was estimated using mean weights from Banfield (1974). Although juvenile ground squirrels were identified in prey remains, we were unable to reliably detect juveniles using direct observation or prey remains in order to correct biomass estimates. Average mass of small mammals and birds was calculated by averaging mean weights from Dunning (1984) for birds and Banfield (1974) for small mammals, for the species identified in prey remain and pellets.

I divided the breeding cycle into 8 stages; incubation, weeks 1 to 6 of brood-rearing, and fledging. All pairs were incubating prior to our first observation period, therefore the incubation stage included all observation periods prior to hatching. The end of the incubation

stage, and beginning of the brood-rearing stage was based on the mean hatching date (n=4 pairs). Each week of brood-rearing accounted for one stage (BR1 to BR6) of the nesting cycle. The end of the brood-rearing stage and beginning of the fledging stage was based on the mean fledging date.

Analysis of Prey Remains in the Nest and at Plucking Sites

Prey remains and pellets were collected from the nests, at the base of the cliff, and at plucking sites once per month at each of 8 sites. Plucking sites were mapped by observers at the nest site and occurred along the tops and faces of cliffs adjacent to the nest site. We removed all prey remains prior to the first collection, and after each subsequent collection to prevent recording prey items twice. At the first collection, weathered, or obviously aged items were discarded as they were judged to have been from the previous year. Food items were identified to species, if possible, with the aid of museum specimens. Prey remains were sorted by species, and the minimum number of individuals was determined by counting the most frequently occurring bone or body part that represented one individual (e.g. femurs, feet, mandibles) in each collection of prey remains. Pellets were examined macroscopically and often provided evidence of smaller prey species such as passerines and microtines. Any prey item in the pellet that appeared to duplicate a previously counted item was not considered an additional individual (Collopy 1983).

Statistical analysis were evaluated at $P \leq 0.05$. All means are reported with standard errors, unless otherwise noted.

2.3 RESULTS

Diet

We identified 203 individual prey items from pellets and prey remains collected in 1989 and 1990, composed of eighteen species of birds and three species of mammals (Table 2-1). Western Meadowlark (Sturnella neglecta), Horned Lark (Eremophila alpestris), European Starling (Sturnus vulgaris), and ducks were the most common avian prey. Sizes of prey taken ranged from 18.9 g (Chestnut-collared Longspur Calcarius ornatus) to 1082.0 g (Mallard Anas platyrhynchos). Diet composition, based on pellets and prey remains, included 53% birds, 44% Richardson's Ground Squirrels, and 3% microtine rodents. Trace amounts of insects were recorded from pellet analysis.

TABLE 2-1. Diet composition recorded from prey remains and pellets collected at 8 Prairie Falcon nest sites in the Bow River Study Area, southern Alberta, 1989-1990.

	# Prey Individuals	% Prey Indiv.	Mass(g)[a]	Biomass(g)	% Biomass
BIRDS					
Blue-winged Teal (*Anas discors*)	2	0.9	386.0	772.0	1.0
Mallard (*Anas platyrhynchos*)	2	0.9	1082.0	2164.0	2.8
Unidentified Ducks	11	5.4	734.0[b]	8074.0	10.4
Total Duck	15	7.2	-	11010.0	14.2
Red-winged Blackbird (*Agelaius phoeniceus*)	3	1.5	52.6	157.8	0.2
Chestnut-collared Longspur (*Calcarius ornatus*)	4	1.9	18.9	75.6	0.1
Eastern Kingbird (*Tyrannus tyrannus*)	1	0.5	39.5	39.5	0.0
Horned Lark (*Eremopila alpestris*)	17	8.4	31.4	533.8	0.6
House Sparrow (*Passer domesticus*)	3	1.5	27.7	83.1	0.1
Vesper Sparrow (*Pooecetes gramineus*)	4	1.9	25.7	102.8	0.1
Western Meadowlark (*Sturnella neglecta*)	24	11.8	97.7	2344.8	3.0
European Starling (*Sturnus vulgaris*)	14	6.8	82.3	1152.2	1.4
Total Passerine	70	34.3	-	4489.6	5.8
Sandpiper spp. (*Caladris* spp.)	2	0.9	24.1	48.2	0.0
Killdeer (*Charadrius vociferus*)	3	1.5	96.6	289.8	0.3
Wilson's Phalarope (*Phalaropus tricolor*)	1	0.5	59.4	59.4	0.0
Black-bellied Plover (*Pluvialis squatarol*)	1	0.5	220.0	220.0	0.2
Ring-billed Gull (*Larus delawarensis*)	1	0.5	518.5	518.5	0.6
Franklin's Gull (*Larus pipixcan*)	1	0.5	280.0	280.0	0.3
Total Shorebird	9	4.4	-	1415.9	1.8
Rock Dove (*Columba livia*)	5	2.5	542.0	2710.0	3.5
Guinea Fowl	1	0.5	389.5	389.5	0.5
Unidentified birds	8	3.9	-	-	-
Total birds	108	53.2	-	40406.8	52.4
MAMMALS					
Mouse/Vole (Cricetidae)	1	0.5	28.8	28.8	0.0
Meadow Vole (*Microtus pennsylvanicus*)	3	1.5	36.5	109.5	0.1
Deer Mouse (*Peromyscus maniculatus*)	1	0.5	21.0	21.0	0.0
Total microtine	5	2.5	86.3	159.3	0.2
Richardson's Ground Squirrel (*Spermophilus richardsonii*)	90	44.3	405.0	36450.0	47.1
Total mammals	95	46.8	-	36609.3	47.3
Total all species	203	-	-	77016.1	100.0

NOTE: [a] After Banfield (1974) and Dunning (1984).
[b] average biomass of all ducks, n=15

In 1989 and 1990, we observed falcons for 227 hours on 32 days and for 460 hours on 56 days, respectively. We directly observed 250 prey items being delivered to nest ledges or fed to nestlings. Diet, based on number of individual prey items, included 68% ground squirrels, 27% birds, and 5% microtines (Table 2-2). Avian prey could not be identified by species but all were called small or less than 100 g by weight.

Comparison of Techniques

A significantly higher proportion of ground squirrels occurred in Prairie Falcon prey deliveries (64%) than was found in pellets and prey remains (44%) (X^2=5.99, df=1, $p<0.05$). Direct observation enabled us to determine sexual differences in prey delivery rates and the type of prey delivered. Prey remains and pellets were useful in identifying prey species in Prairie Falcon diet. Using direct observation only 30% of bird prey, and no small mammals were identified to species. We did not observe delivery of ducks or other large avian prey (>100 g) to the nest site, however, these birds are present in prey remains and comprise 19.5% of the total prey biomass (TPB). Small avian prey (<100 g), representing 70% of total prey individuals (TPI), accounted for only 6.3% of TPB. In early June, juvenile song birds were detected in prey remains. Therefore, pellets and prey remains provided additional information about Prairie Falcon diet and were essential for identification of prey species.

Seasonal Variation in Diet

Frequency of birds versus mammals in the diet, based on direct observation, did not differ between years 1989-90 or among nesting pairs (x^2=1.23, df=1, P>0.05, and x^2=7.46, df=6, P>0.05, respectively).

Variation in diet between the sexes, based on direct observation, was analyzed from incubation to dispersal for 1989 and 1990. During incubation male and female falcons hunted only ground squirrels (Fig. 2-1). Throughout the first 5 weeks of brood-rearing, male falcons fed primarily on ground squirrels and secondarily on birds (Fig. 2-1). During week 6 of brood-rearing and fledging, birds were the primary prey of male falcons. Use of ground squirrels by male falcons decreased from week 2 of brood-rearing through to fledging, while female delivery rates of ground squirrels doubled during week 2 and 3 of brood-rearing (Fig. 2-1). Female falcons delivered primarily ground squirrels throughout the nesting cycle.

TABLE 2-2. A comparison of two methods used to determine the summer diet of Prairie Falcons (n=8 pairs) nesting in the Bow River Study Area, 1989-1990.

Method of Diet Determination	Prey	No. Prey	% Prey	Average Mass(g)[a]	Prey Biomass	%Prey Biomass
Direct Observation	Ground Squirrel	169	67.6	405	68445	93.5
	Bird (<100 g)	67	26.8	64	4288	5.9
	Bird (>100 g)	0	-	-	-	-
	Microtine	14	5.6	32	448	0.6
Total Prey		250			73181	
Prey Remains and Pellets	Ground Squirrel	90	44.3	405	36450	64.4
	Bird (<100 g)	76	37.4	64	4864	8.6
	Bird (>100 g)	24	11.8	630	15120	26.7
	Bird unidentified	8	3.9	-	-	-
	Microtine	5	2.5	32	159	0.3
	Total Prey	203			56593	

NOTE: [a] After Banfield (1974) and Dunning (1984).

Females delivered only ground squirrels up to week 4 of brood-rearing, then during the last half of the nesting cycle (BR4 to fledging) birds were secondary prey. Overall, male falcons delivered 32% birds, while females delivered only 11% birds. Young falcons were observed feeding on insects on the ground near the nest during the fledging stage.

During the first 3 weeks of brood-rearing, females flew off the nest ledge to meet the incoming male, received prey and then returned to the nest to feed young. Between feedings the female brooded young. When the chicks were approximately 4 weeks old, male and female falcons dropped food at the nest ledge and chicks fed themselves. Overall, 25% of the prey items delivered by male Prairie Falcons were delivered directly to the young, and the remaining 75% were delivered to the female, who then fed the young.

Foraging trips by Prairie Falcons ranged in duration from 8 to 103 minutes, and trips where they captured birds (29±4.2 minutes, n=15) were significantly shorter than those where they captured

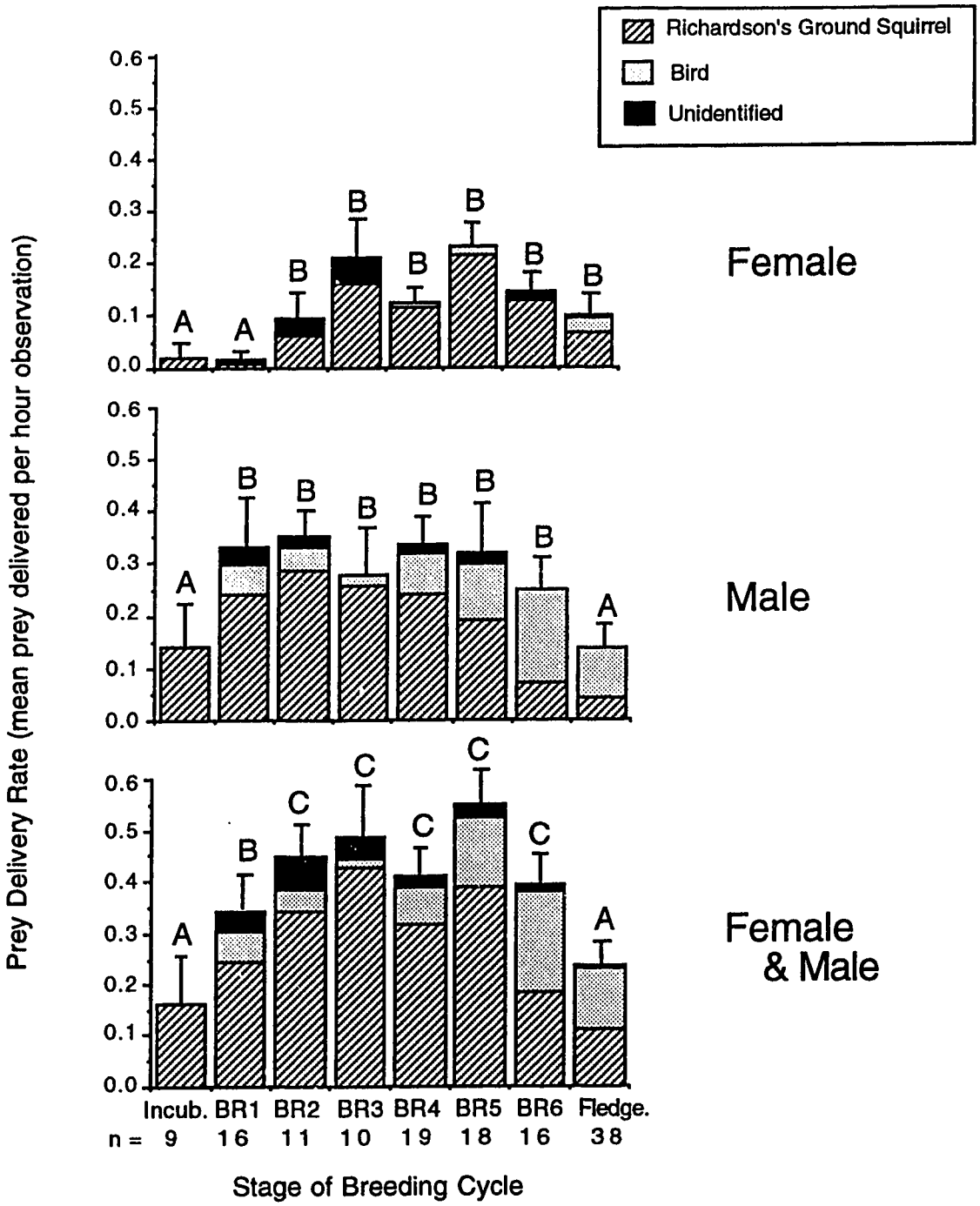

Figure 2-1. Mean prey delivery rate at 8 Prairie Falcon nest sites throughout the breeding cycles in 1989 and 1990 (x ± SE). "n" = number of observation periods. BR1 to BR6 = weeks 1 to 6 of brood-rearing. Periods with the same letter are not significantly different.

ground squirrels (57±4.4 minutes, n=35; t=3.88, P<0.05). Deliveries of ground squirrels peaked during mid morning, early afternoon and early evening hours (Fig. 2-2). Deliveries of bird prey fluctuated throughout the day, and (except between 1600-1700 hours) were consistently lower than delivery rates of ground squirrels.

No significant differences in prey delivery rates per pair were detected between years or among the nesting pairs (Mann-Whitney, U=2056, p>0.05; Kruskal-Wallis, df=7, p>0.05, respectively). Comparisons between nesting pairs were calculated using pooled data from stages BR4, BR5, and BR6 where there was minimum variation in sampling effort between sites.

Because no differences were detected between years or among nesting pairs, prey delivery rates were pooled for sites and years. A significant difference was detected among stages of the breeding cycle (Kruskal-Wallis, df=7, p<0.05; Fig. 2-1). Differences between stages of the breeding cycle were detected using a nonparametric multiple comparisons test (Zar 1984). The lowest delivery rates were observed during the incubation stage (Fig. 2-1). Prey delivery rates during fledging and incubation did not differ significantly from each other, but were significantly lower than delivery rates in any other stage (0.24±0.29, observation periods [OP]=38 and 0.16±0.27, OP=9, respectively). Prey delivery rates peaked during weeks 2 to 6 of brood rearing (0.46±0.33 items/hr, OP=74) and were significantly higher than during any other stage. There were no significant differences in prey delivery rates among weeks 2 to 6 of brood-rearing, however, prey delivery rate during week 1 of brood-rearing (0.34±0.38, OP=16) was significantly lower than during other brood-rearing stages.

Diet Variation Between Male and Female Falcons

Food delivery was not shared equally between both members of each pair. Male Prairie Falcons delivered 69% of all prey to the nest site at a mean rate of 0.25±0.26 items per hour (OP=137) over the entire nesting period. During incubation, males delivered 86% of the prey at a mean rate of 0.14±0.23 items per hour (OP=9). The rate of prey deliveries increased immediately after hatching to a mean rate of 0.35±0.16 items/hr (OP=11) during the second week of brooding, and stabilized at approximately 0.32 items/hr for weeks 1 to 5 of brood- rearing. During week 6 of brood-rearing, prey delivery rate decreased to 0.25 ± 0.23 items/hr. (OP=16).

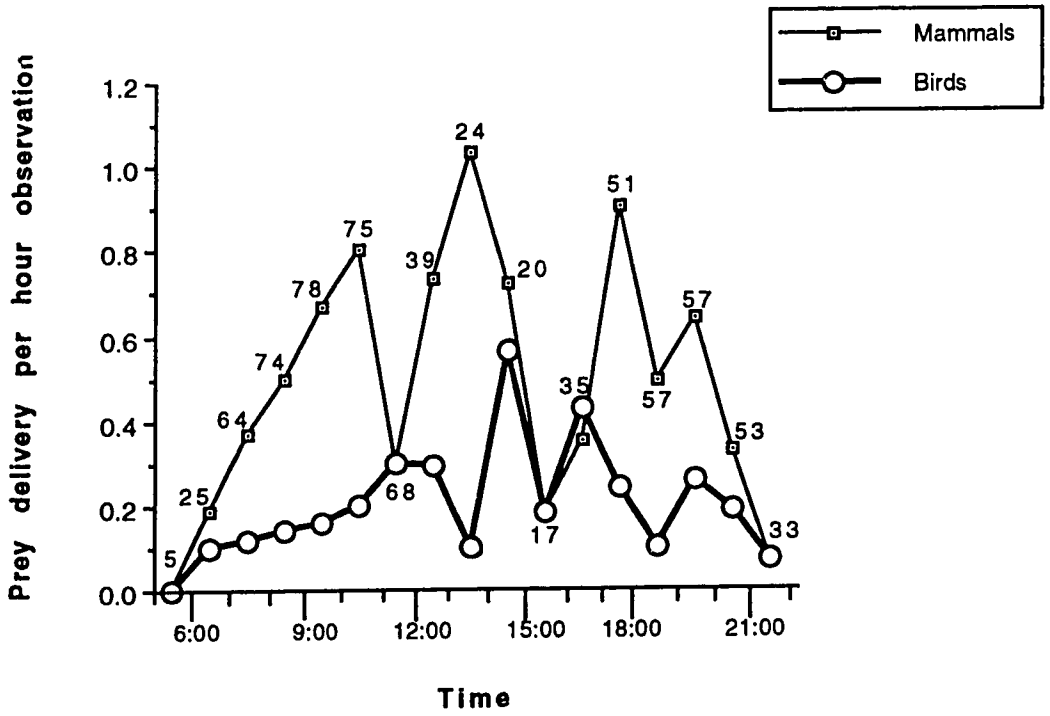

FIG. 2-2. Delivery rates of ground squirrels and birds to Prairie Falcon nest sites (n=8) in the Bow River Study Area, 1989 and 1990. Numbers on the figure represent total hours of observation for each hourly time interval.

Female Prairie Falcons delivered only 14% of prey items to the nesting territory during incubation. Females increased their prey delivery rates during the third week of brood rearing, when young were 21-27 days of age, about 2 weeks after the peak in prey deliveries by the male. The maximum contribution by females occurred during weeks 3 to 5 of brood-rearing, when they delivered an average 39% of the prey to the nestlings (range 30-44%). Female prey delivery rates did not surpass male delivery rates during any stage of the nesting cycle. During week 6 of brood-rearing, female prey delivery rate decreased to 0.144 $\pm$0.143 items/hr (OP=16).

Overall, prey delivery to the nest increased from incubation to brood-rearing stage 5, with the exception of stage 4. The rate of food delivery declined at the end of brood-rearing and at fledging (Fig. 2-1).

2.4 DISCUSSION

Diet

A wide range of prey species were eaten by Prairie Falcons in the Bow River Study Area, but a few species account for a majority of the diet. Richardson's Ground Squirrels and birds dominated the diet of nesting Prairie Falcons, with ground squirrels being the primary prey. Ground squirrels have been reported as the primary prey in Idaho (Ogden and Hornocker 1977, Sitter 1983, Steenhof and Kochert 1988, Holthuijzen 1990), Wyoming (Enderson 1964, MacLaren, et al. 1988), northern Colorado (Enderson 1964), and northern California (Haak 1982). In other regions nesting Prairie Falcons forage primarily on avian prey (Marti and Braun 1975, Boyce 1985). As in this study, Horned Lark (Steenhof and Kochert 1988, Squires et al. 1989) and Western Meadowlark (Fowler 1931, Enderson 1964, Leedy 1969, Platt 1974, Denton 1975, Squires et al. 1989) have been previously reported as important avian prey for Prairie Falcons.

Trace amounts of insects were recorded from pellet analysis and fledged young were observed catching and eating insects on the ground near the nest site. Other studies have recorded insect remains in Prairie Falcon pellets (Bond 1936b, Ogden and Hornocker 1977, U.S. Department of the Interior 1979, Holthuijzen et al. 1987). Bond (1936b) and Holthuijzen et al. (1987), observed Prairie Falcon catching insects in flight. Bond (1936b) reports that while the thorax and abdomen are crushed and swallowed, the wings and legs of insects are often discarded. This behaviour may explain why insects or insect parts were rarely found in pellet analysis. Reptiles have occasionally been recorded in the diet of Prairie Falcons by other workers (Ogden and Hornocker 1977, Boyce 1985); five species of snakes occur in the BRSA (Cook 1984), but snakes were not recorded in the diet.

Comparison of Techniques

While many authors agree that pellets and prey remains give an inaccurate indication of the total number of individual species (Craighead and Craighead 1956, Newton and Marquiss 1982, Steenhof and Kochert 1988), many use remains and pellets to reflect relative frequencies of prey types in the diet (Collopy 1983, Sitter 1983, Steenhof and Kochert 1988). To determine the accuracy of collections of prey remains and pellets in determining the relative frequencies of prey types in the diet, I compared estimates of diet composition based on pellets and prey remains with direct

observations of prey delivered to the nest. Estimates derived from prey remains and pellets represented a minimum number of individuals and it is unlikely that the number of bird or mammal individuals could have been overestimated. I therefore conclude that examination of pellets underestimated ground squirrels.

Under representation of squirrels in prey remains and pellets may be explained by the prey preparation behaviour of adult falcons. Sodhi (1992) found that male Merlins (Falco columbarius) were more likely to prepare prey at greater distances than near the nests. In the BRSA, bird prey were hunted in close proximity to the nest (Chapter 3), and were usually delivered to the nest area whole, then plucked and prepared near or at the nest site. Feet, primaries, wings, tail and other large feathers were usually discarded and frequently identified in prey remains. In some cases only a few feathers from an individual bird remained. Ground squirrels were hunted an average distance of 10 km from the nest (Chapter 3) and were rarely delivered whole to the nest site. Prey remains showed that over 50% of the squirrels delivered to the nest, consisted of only the hind quarters (pelvis, hind legs or tail). Observations also verified that squirrels were rarely delivered whole to the nest. The residual carcass, large bones, and skin of both mammals and birds are often discarded from the nest by adult falcons (Sitter 1983). Preparation of ground squirrels at the kill site rather than near the nest site in combination with discarding of carcasses away from the nest site, likely contributed to the underrepresentation of ground squirrels in prey remain and pellet collections. In contrast, even a few feathers could be used to identify avian prey.

The value of studying pellets and prey remains was to provide detailed information that aided in age and species identification of prey. Only 30% of avian prey was identified to species by direct observation, and larger avian prey (>100 g) were not detected at all. Ducks, for example, contributed 14 % TPB and were detected only by analysis of prey remains. Larger bones and primary feather of ducks were found in the remains, therefore, ducks were carried to the nest area and contributed to nestling diet. If ducks were prepared and partially consumed by adult falcons prior to their delivery to nest sites, observers probably didn't recognize the duck prey and categorized it as an unidentified bird. Thus, direct observation alone can provide an incomplete assessment of Prairie Falcon diet. Pellets are also important for detecting the smaller prey items often underestimated in collection of prey remains alone (Errington 1932; Poole and Boag 1988). In this study, all microtine prey was

identified to species using pellets, but the proportion of microtines in the diet was still underestimated. This underestimation, however, appears to have minimal impact on diet analysis in terms of total prey biomass.

Details of Prairie Falcon feeding habits are essential in determining accurate estimates of prey biomass. Comparison of techniques showed that percent total prey individuals and consequently percent total prey biomass of ground squirrel prey was underestimated in the collections of prey remains and pellets. Small avian prey (<100 g), accounting for the majority of avian prey individuals, contributed little to the total biomass of birds. Rather, the relatively few larger avian prey individuals made up the majority of the biomass of birds. In this study, biomass estimates were computed from average adult prey weights, while juvenile prey species were common in the diet. Further, biomass of the entire prey item and the actual amount delivered to the nest differed. Thus, to obtain accurate estimates of prey biomass, the weights of prey species should be adjusted to represent the actual weights of prey (or prey part) delivered to the chicks.

During the breeding season, Prairie Falcons bring prey items one at a time to the nest, and are referred to as central place foragers (Krebs et al. 1983). Central place foragers have also been reported to eat small prey away from the central place, but to transport larger prey items (Rudolph 1982, Carlson 1985, Krebs et al. 1987, Bull et al. 1989, Sonerud 1989). In this study, observations at the nest are used to estimate the diet of young. Feeding by adult falcons may be occurring away from the nest area, and may be represented in the analysis of pellets.

Seasonal Variation in Diet

Based on patterns of food consumption, Newton (1979) divided diurnal raptors into two groups. Group one, including Peregrine Falcon, Osprey (Pandion haliatetus), and several harrier species (Cirus spp.), was characterized by an increase in total food consumption during the nestling period and with the number of young; the female did not hunt before the young had fledged. In group two, including several accipiters, food consumption did not increase with age and the number of young; the female started hunting before the young had fledged. Holthuijzen (1990) reported that Prairie Falcons do not belong to either group, but occupy a position along a continuum with the two groups at the extremes. The pattern of food consumption by Prairie Falcons in the BRSA agrees with findings by

Holthuijzen (1990). Prey delivery rate increased significantly between weeks 1 and 2, but not between weeks 2 and 6, of the nestling stage. Females hunted throughout the incubation stage at a very low rate, and provided prey at an increasing rate during the brood-rearing stage.

No yearly variation in the proportion of ground squirrels and birds in the diet was detected, however variation in diet composition throughout the nesting cycle was observed. While the effects of annual variations in prey densities on Prairie Falcon selectivity for prey have been examined (Peterson et al. 1977, Steenhof and Kochert 1988), response of raptors to variation in prey abundance during the nesting cycle is not well documented. In this study, direct observation showed a "switching" behaviour with male falcons preying more on birds than squirrels during the later part of brood-rearing. Female falcons also delivered birds during the last half of the nesting cycle, while no birds were hunted during the first half. Changes in diet composition may be in response to the summer hibernation of adult ground squirrels in combination with a seasonal abundance of vulnerable juvenile birds and post breeding adult birds. If squirrels were equally abundant throughout the nesting cycle, I would expect both male and female falcons to continue to hunt squirrels as the nesting season progressed and food demands of the young increased.

While activity patterns of Richardson's Ground Squirrels are not well documented in our study area, it is likely that the pattern in ground squirrel deliveries by Prairie Falcons reflects the activity pattern of their main prey species. In Idaho, Johnson et al. (1977) found that as the season progresses, above-ground activity of the Townsend's Ground Squirrel becomes more bimodal with a morning and late afternoon peak. Similar relationships have been found for other raptors in relation to small mammal activity during the day (Runsdorp et al. 1981, Raptor Group RUG/RIJP 1982), and has been previously noted for Prairie Falcons (Smith and Murphy 1973, Ogden and Hornocker 1977, Haak 1982). Radiotelemetry (unpubl. data) confirmed that early afternoon feedings did not involve long distance foraging trips from the nest. Thus, the early afternoon peak in deliveries of ground squirrels (Fig. 2-2) may represent feedings from caches.

Increase in prey size selected by Prairie Falcons from incubation to the nestling period has been previously observed (Edwards 1973, Haak 1982). Variation in diet composition during the nesting cycle could bias diet studies conducted during only a portion of that cycle.

Diet Variation Between Male and Female Falcons

The reversed sexual size dimorphism that exists in most raptor species, often has been interpreted as an adaptation to facilitate the capture of different sized prey, thereby expanding the food niche and reducing intersexual competition for food (Selander 1966, Storer 1966, Earhart and Johnson 1970). The food niche hypothesis is supported by my findings that female Prairie Falcons delivered primarily Richardson's Ground Squirrels, while males delivered more birds. Direct observation recorded only small bird prey (<100 g) being delivered by male falcons, while the origin of larger avian prey (>100 g) is unknown. Difference in diet of male and female falcons was most pronounced late in brood rearing when food demands were high and the primary prey was perhaps less available. In addition, the males may reduce their hunting time on ground squirrels since the females are hunting more on a limited number of colonies of ground squirrels. I speculate that it would be inefficient for males and females to hunt at the same colony since ground squirrels may reduce their above ground activity if falcons appear frequently.

An alternative hypothesis to explain the increase in bird prey taken by males relates to the behavior of older nestlings. In early brood rearing the female dismembers large ground squirrel and appears to feed all nestlings in her brood. Later, when the nestling's feed themselves, a nestling in possession of prey, will mantle the prey and feed on it to the exclusion of other young. By delivering smaller bird prey, the prey delivery rate is increased, ensuring that each nestling has at least a smaller bird for food.

Procurement of food was not shared equally between sexes of each pair. Female prey delivery rates, from incubation to after fledging, did not exceed prey delivery rates of male falcons. Males provided most of the prey to the female and the chicks from incubation to approximately week 2 of brood rearing. Females increased their contribution to the food supply, which peaked when young stabilized in weight at about 24 days of age (Fowler 1931, Sitter 1983). This pattern of food delivery and supplementation by the female may reflect a limited capacity in the male for prey capture and a need for the female to hunt late in chick rearing (Collopy 1984). It may also result from the ability of young to feed themselves and thermoregulate, freeing the female to hunt. On average, adults fed individual young up to 5 weeks old. From 5 weeks of age to post-fledging, quarry was delivered to the site and young fended for themselves. Prey delivery rates decreased during

the final week of brood rearing. Brown (1955) suggested that Golden Eagle (Aquila chrysaetos) parents intentionally reduced their food supply to offspring late during chick rearing and that this reduction facilitated the fledging process. An alternative hypothesis is that young stabilize their weight at approximately 24 days of age (Fowler 1931, Sitter 1983), and therefore have lower demands for volume of food.

Conclusions

In summary, direct observation supplemented with analysis of prey remains and pellets, provides the most complete estimates of diet for nesting Prairie Falcons. Direct observation accurately represents the proportions of prey types being delivered to the nests, while pellets and prey remains provide complete information about age, sex, or species of smaller prey. Therefore, combining these two techniques, provides a complete estimate of the proportions of prey species used by nesting Prairie Falcons during the nesting cycle.

In southern Alberta, Richardson's Ground Squirrels were primary prey of nesting falcons, and waterfowl and songbirds were secondary prey. Females increased their contribution to prey delivery as the nesting season progressed, hunting primarily ground squirrels. The proportion of bird prey versus ground squirrel prey, delivered by the male falcon increased as the nesting cycle progressed. This increase in bird prey delivered by male falcons may be related to prey availability and/or the need to provide many prey items to young.

Conservation of Prairie Falcons must include protection of ground squirrel colonies, wetlands for waterfowl, and native range for songbirds. In Idaho, researchers identified a direct relationship between the abundance of Townsend's Ground Squirrels and Prairie Falcon reproductive success (U.S.D.I. 1979). In Alberta, managers should focus on maintaining squirrel colonies within close proximity to prairie rivers with potential Prairie Falcon nest sites. Further, researchers should initiate long term studies to determine the habitat requirements and population trends of Richardson's Ground Squirrels.

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3.0 HOME RANGE SIZE AND HABITAT USE OF PRAIRIE FALCONS (FALCO MEXICANUS) NESTING IN AN AGRICULTURAL LANDSCAPE IN SOUTHERN ALBERTA.

3.1 INTRODUCTION

In Prairie Canada, the Prairie Falcon nests in cavities in cliffs along rivers and forages over adjacent lands. While cliff nest sites are relatively secure, foraging areas are not. In western Canada, more than 80% of the native prairie landscape has been transformed by agriculture, urbanization, and industrialization (World Wildlife Fund Canada 1988). Consequently, the prairie landscape is a highly fragmented patch-work of cultivated and uncultivated lands. Within this landscape mosaic, areas rich in prey species are scattered throughout areas poor in prey. While considerable effort has been focused on estimating home ranges of Prairie Falcons, fewer studies have examined the disproportionate availability and use of habitats within the home range. Those areas within a defined range where use exceeds that expected from a uniform distribution are called core areas (Samuel et al. 1985). Identifying core areas used by Prairie Falcons is an important part of understanding the ecological factors that determine habitat use or suitability.

Most information available on the habitat use of Prairie Falcons has been collected from studies in the United States (Harmata et al. 1978, Haak 1982, Holthuijzen et al. 1990, Beauvais et al. 1992, Squires et al. 1993). Home range and habitat use of Prairie Falcons nesting in western Canada may differ from other areas because land use and prey species differ.

The first objective of this study was to identify home ranges, foraging ranges, and core foraging areas used by breeding Prairie Falcons in southern Alberta. Secondly, I wanted to compare proportions of habitat types within used areas (home ranges and core foraging areas) to those of unused areas. In this study, home range refers specifically to the area used by a breeding individual from one week after hatching of young to nestling dispersal. Foraging ranges describe areas within the home range that were used specifically for hunting, and were identified by tracking individual falcons throughout foraging trips. Core areas within the foraging ranges represent areas where use exceeds that expected from a uniform distribution. Foraging ranges and core areas of use within foraging ranges are divided into those used on hunting trips

where 1) bird prey, or 2) Richardson's Ground Squirrel (Spermophilus richardsonii) prey are delivered. I also examined overlap in home ranges and core areas between adjacent pairs of nesting falcons and within pairs. The intensity of use of core areas when ground squirrel prey was delivered is compared to that of core areas when bird prey was delivered.

3.2 METHODS

Study Area

The Bow River Study Area (B.R.S.A.) encompasses a 120 km stretch of the Bow River in southern Alberta and is characterized by badlands, river coulees, grazing reserves, and intensive agriculture (Fig. 3-1). The study area covers approximately 7500 km^2, located within the Short Grass Ecoregion (Strong and Leggat 1992). Sand and clay cliffs up to 40 meters high, with occasional benches and buttes, border the river and provide numerous nesting and roosting sites for Prairie Falcons (unpubl. data).

A 1989 landsat image and SPANS geographic information system (GIS) were used to initially divide the study area into seven ground cover categories: native range 1 (2.9% of total area), native range 2 (42.5%), tame range (11.2%), bare ground (4.2%), dryland crop (7.2%), irrigated crop (28.1%), water (3.7%), and other (22.6%) (Table 3-1; modified from Usher 1993). Discriminant function analysis for classification accuracy was conducted for each habitat category (Table 3-1). Tame range, bare ground, and dryland crop received accuracy assessments of less than 65%, indicating that each category contained elements of other cover categories. Thus, for the purpose of this paper, we combined these three categories into one category labelled other crops. Patches of native range 1 almost always contained Richardson's Ground Squirrel colonies, while patches of native range 2 did not. Crop production includes sugar beets, alfalfa, vegetables, corn, wheat, oats, and barley.

Radio Tracking Falcons

To avoid causing nest abandonment, we trapped birds one week after hatching. Fourteen adult Prairie Falcons were trapped at nest sites using noose carpets, and were fitted with 216-mHz radio transmitters using a tail mount (15 g) or backpack harness of Teflon tubing (18 g). Tail mounts were attached to the rachis of two central tail feathers with dental floss and crazy glue. All tail mounts were molted with the

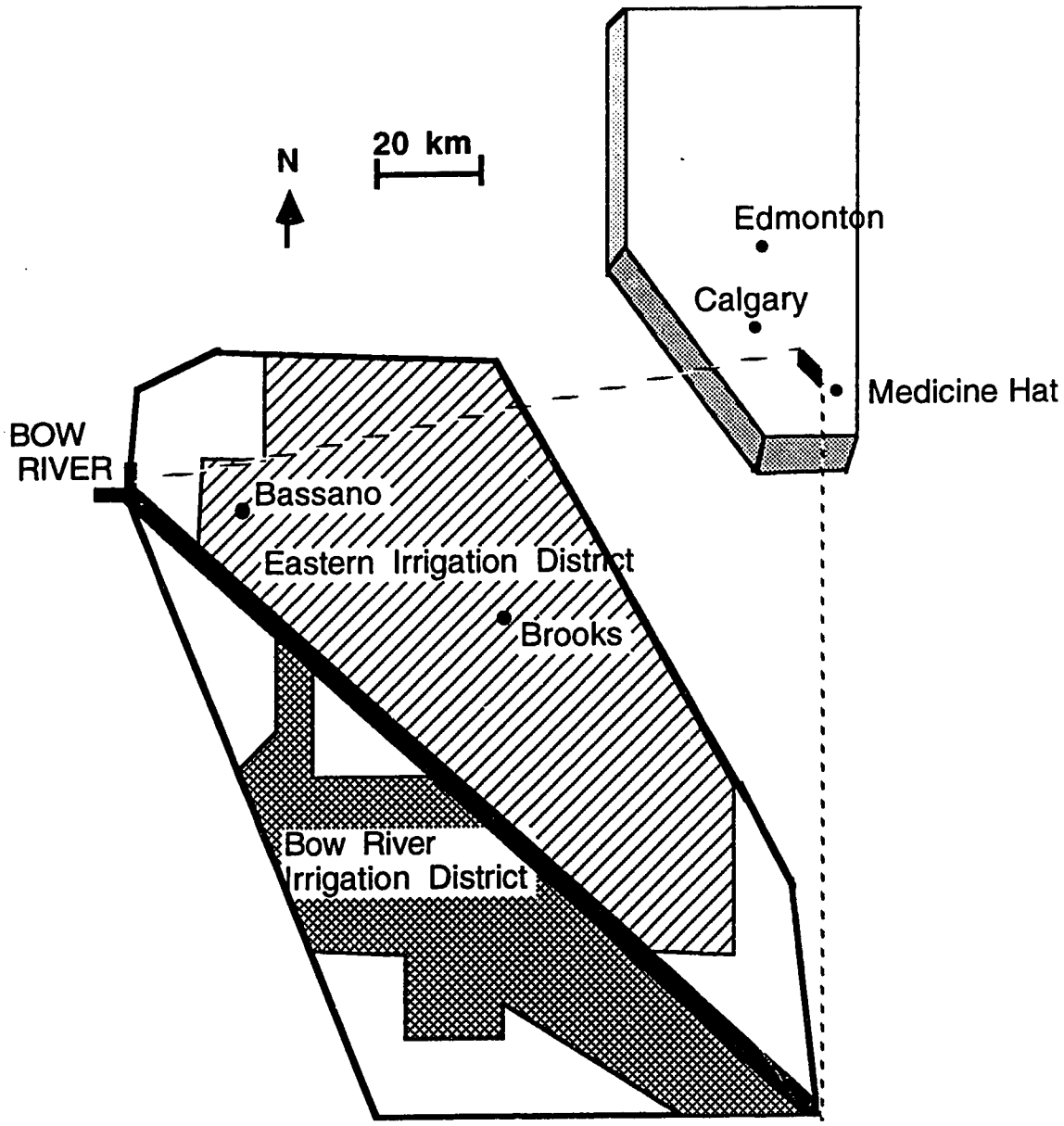

Figure 3-1. Schematic diagram of the Bow River Study Area in southern Alberta, Canada.

Table 3-1. Description and classification accuracy of five ground cover categories in the Bow River Study Area in southern Alberta (modified from Usher 1993).

Cover Category	Classification Accuracy Assessment(%)	Description
1.Native Range 1 (uncultivated)	87.5	Unbroken prairie grassland characterized by needle and thread grass (Stipa comata) in combination with western wheatgrass (Agropyron smithii) and thread-leaved sedge (Carex filifolia). Pasture sage (Artemisia frigida) and scarlett mallow (Maluastrum coccineum) are important forbs. Mosses and lichens are common. Richardson's Ground Squirrel colonies are common.
2.Native Range 2 (uncultivated)	70.0	Unbroken prairie grassland characterized by needle and thread grass in combination with northern wheatgrass (Agropyron dasystachyum) blue grama grass (Bouteloua gracilis), June grass (Koelaria cristata) and thread-leaved sedge. Sage (Artemisia spp.) and moss phlox (Phlox hoodii) are important.
3. Other-Tame Range Crop (cultivated)	50.0	Sown with Russian wild rye (Elymus junceus) or crested wheatgrass (Agropyron cristatum).
-Bare Ground	64.3	Exposed soil common to both tame range and dryland crop.
-Dryland Crop	55.6	Characterized by strips of alternating cropland and adjacent fallow fields.
4.Irrigated Crop (cultivated)	66.7	Irrigated crops and wetland vegetation (<10%).
5. Water	65.3	Rivers, lakes, irrigation canals, and other wetland areas.

approximately the same time that young fledged and adults dispersed. In 1989, the antenna on a tail mount attached to a male falcon was damaged approximately one week after attachment, and another male falcon died. Therefore, a total of 5 male and 7 female falcons are included in analyses.

Falcons were tracked from late May through July, 1989 to 1990. Tracking periods were most frequent between 0500 to 1200 hours and 1600 to 2200 hours, and included all time periods when a single falcon was detected to be flying away from the nest. An observer with a hand held radio, positioned near the nest site, reported to trackers when a bird left the nest site. One falcon was tracked per tracking period. Radio-marked birds were followed by 2 to 3 observers with hand-held 3 and 6 element Yagi antennas and portable receivers, in a vehicle or on foot. Birds were continuously monitored and compass bearings (fixes) were taken at 2 min. intervals. If a bird flew out of receiving range, we recorded the next location when the bird was relocated.

Maximum range for signals was 15 to 20 km under favorable conditions. We did not use fixed triangulation stations, so error polygons for each fix were not calculated (Nams and Boutin 1991). Triangulations with polygons greater than 50 ha were not included in the analysis. Based on the mean size of triangulation polygons (approximately 30 ha), I estimated radio fixes were accurate to within 500 m of the birds actual location.

Home Range

I selected the minimum convex polygon, a non-statistical method, as the most appropriate model to use in calculating home range size (Kenward 1987, White and Garrott 1990). Swihart and Slade (1985) suggested using a nonstatistical method when data must be collected over a short period of time and autocorrelation cannot be avoided. All tracking data were included in home range estimates. Minimum convex polygons were calculated using McPaal.

I used an area-observation curve (Odum and Kuenzler 1955) of minimum convex polygon home range estimates to determine if an adequate number of locations had been collected in order to estimate home range size.

Foraging Range

I calculated foraging ranges of 5 female and 4 male falcons using pooled foraging trips for each bird. Only complete foraging trips, with recorded locations every 2 min. and confirmation of prey

delivered to the nest, were used in this analysis. Foraging trips when bird prey were delivered to the nest (bird foraging trips) were sometimes completed in less than 10 min., and flight speeds of 10 km in less than 8 min. were recorded for foraging falcons. Thus, short time intervals were required to accurately estimate foraging movements. Because the birds were able to travel to any habitat type within their home range within the 2 min. between recorded locations, all ground cover categories within the home range were considered available to the bird for each location. I eliminated tracking sessions with gaps (location of falcon unknown for more than 5 min.) to ensure equal representation of all parts of the foraging trip. Ground squirrel foraging trips refer to foraging trips that resulted in ground squirrels being delivered to the nest site. I measured the maximum distance of individual foraging trips from the nest, and calculated the size (ha) of these trips using a minimum convex polygon. Foraging trips were combined to determine the foraging range for each bird, using the minimum convex polygon. Foraging ranges for ground squirrel foraging trips are described separately from those for bird foraging trips.

Core Foraging Areas

Core areas of use within the foraging range were determined by dividing the study area into 1 km^2 grids and counting the number of radio fixes per grid cell (Samuel et al. 1985). To avoid bias associated with a high number of relocation points near the nest, fixes within 500 m of the nest site were not counted (Squires et al. 1992). I selected a cell size that effectively represented areas or neighborhoods of concentrated use within the known foraging area. Core areas, therefore, do not represent precise locations of high use, but represent 1 km^2 neighborhoods of relatively high use compared to the rest of the foraging area. The intensity of use of the core areas was tested for significance using a one-sided Kolmogorov-Smirnov goodness-of-fit procedure (Zar 1984). Grid cells having a fix density that was less than expected (Samuel et al. 1985) were excluded from the core area. Core areas used on ground squirrel foraging trips are identified separately from those used on bird foraging trips.

Habitat Availability

An area analysis was performed within the SPANS GIS to determine the availability of habitat types for each Prairie Falcon pair. Because nesting falcons rarely hunted farther than 15 km from

the nest, I considered the area within a 15 km radius of each nest site to be available habitat for that pair (Squires et al. 1993).

Habitat Use

I used SPANS GIS to determine the proportions of habitat types within home ranges, and a grid overlay to calculate the proportion of each habitat type within the 1 km^2 grid cells identified as core areas. I used Wilcoxon matched-pairs signed-rank test to compare proportions of habitat types within each home range and within core foraging areas, to habitat availability within a 15 km radius of each nest site (Zar 1984). The null hypotheses tested was that each habitat type within a home range or core area occurs in proportion to its availability within a 15 km radius of the nest site (Alldredge and Ratti 1986).

Statistical analysis were evaluated at $p \leq 0.05$ and all means are reported with standard errors, unless otherwise noted.

3.3 RESULTS

Home Range

Home range size averaged 7249 ha ± 1357 (n=11), with a range of 3126 to 19203 ha (Table 3-2). The average home range size calculated for male falcons was twice as large (10539 ha ± 2914, n=4) as for female falcons (5370 ha ± 885, n=7). The largest home range, occupied by Corral Prairie 2 male in 1989, was 46% larger than the next largest home range. This bird also had the largest number of fixes (n=292) used to estimate range size. The much larger home range and large sample size for this bird contributed to a significant relationship between home range size and total number of locations (Fig. 3-2). It's range size, however, was still larger (at approximately 11000 ha) than the next largest home range after only half the locations (n=146) had been collected.

Area observation curves, calculated for 7 falcons with more than 3 tracking periods, did not show an asymptotic relationship between cumulative home range size and number of consecutive radiolocations (Fig. 3-3). Therefore, I refer to estimates in this study as minimum home range sizes.

Male falcons hunted more often than female falcons throughout the nesting cycle, which contributed to a larger number of locations (fixes) and tracking periods for male falcons than for female falcons (Table 3-2). Because home range sizes are correlated with the total number of fixes ($p<0.01$), I did not compare range sizes of male and

Table 3-2. Home ranges of 12 Prairie Falcons nesting in southern Alberta, calculated using the minimum convex polygon (MCP).

Falcon Identification	Sex	Year	Fixes	Tracking Periods	Home Range(ha)
Corral Prairie 2	M	1989	292	19	19202.5
Bullsnake	F	1990	64	4	10312.0
Bullsnake	M	1990	170	13	8750.0
Corral Prairie 1	M	1990	214	14	7201.0
Longstreak	M	1990	149	13	7002.5
Slabsluff	F	1990	30	1	5969.0
Corral Prairie 1	F	1989	41	5	4869.0
Longstreak	F	1989	45	2	4793.5
Longstreak	F	1990	47	4	4475.6
Corral Prairie 1	F	1990	14	2	4047.8
Corral Prairie 2	F	1989	29	2	3126.0
Slabsluff	M	1990	8	1	469.5[a]

[a] Because of small sample size (number of locations and number of tracking periods), this estimate was not used to calculate average home range size.

female falcons.

Home ranges of adjacent nesting pairs (those within approximately 2 km of each other) tracked during the same breeding period overlapped considerably, ranging from 38% to 100% (Fig. 3-4a, 3-4b). Within pairs, home ranges of male and female falcons also overlapped, ranging from 45% to 100% (Fig. 3-4a, 3-4b.). Generally, shapes of the home ranges were longer than wide, and extended north of the river. Exceptions were Corral Prairie 2 male whose large range included areas northwest and south of the river (n=19 tracking periods, Fig. 3-4a), and Slabsluff male who ranged south of the river on one tracking period (Fig. 3-4b).

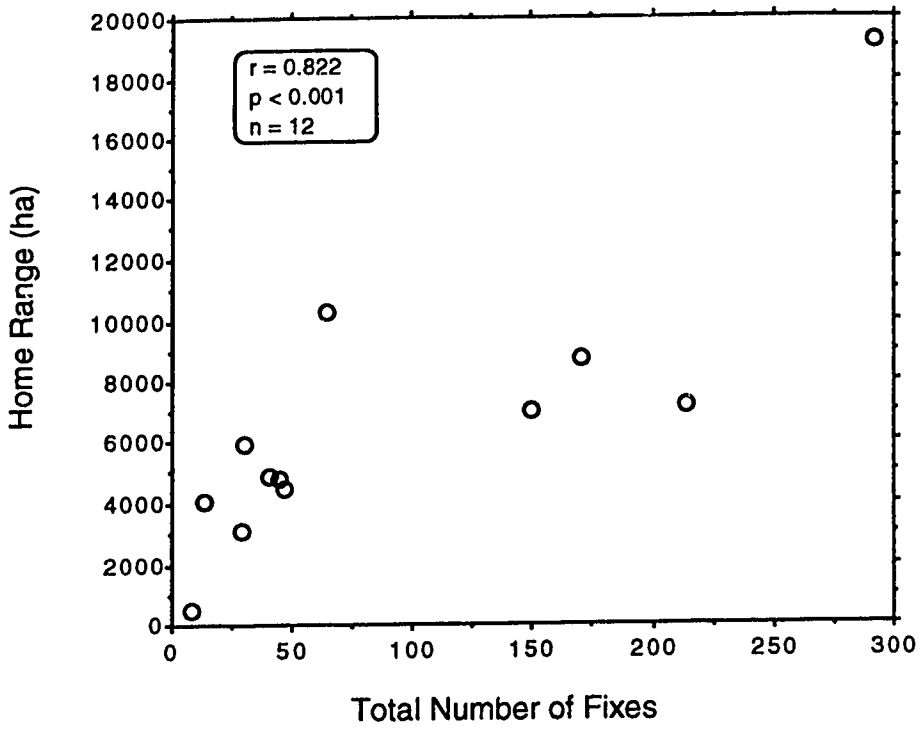

Figure 3-2. Relationship between home range size of Prairie Falcons and the number of fixes used to calculate home range size.

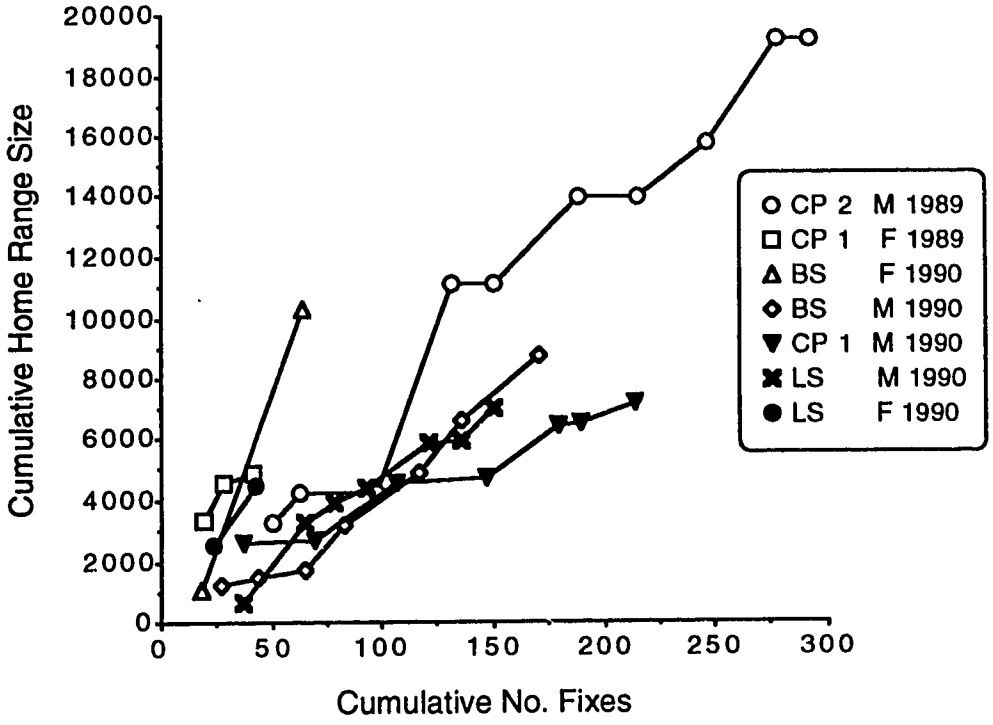

Figure 3-3. Relationship between number of tracking periods and home range sizes for 7 Prairie Falcons nesting in the Bow River Study Area, southern Alberta.

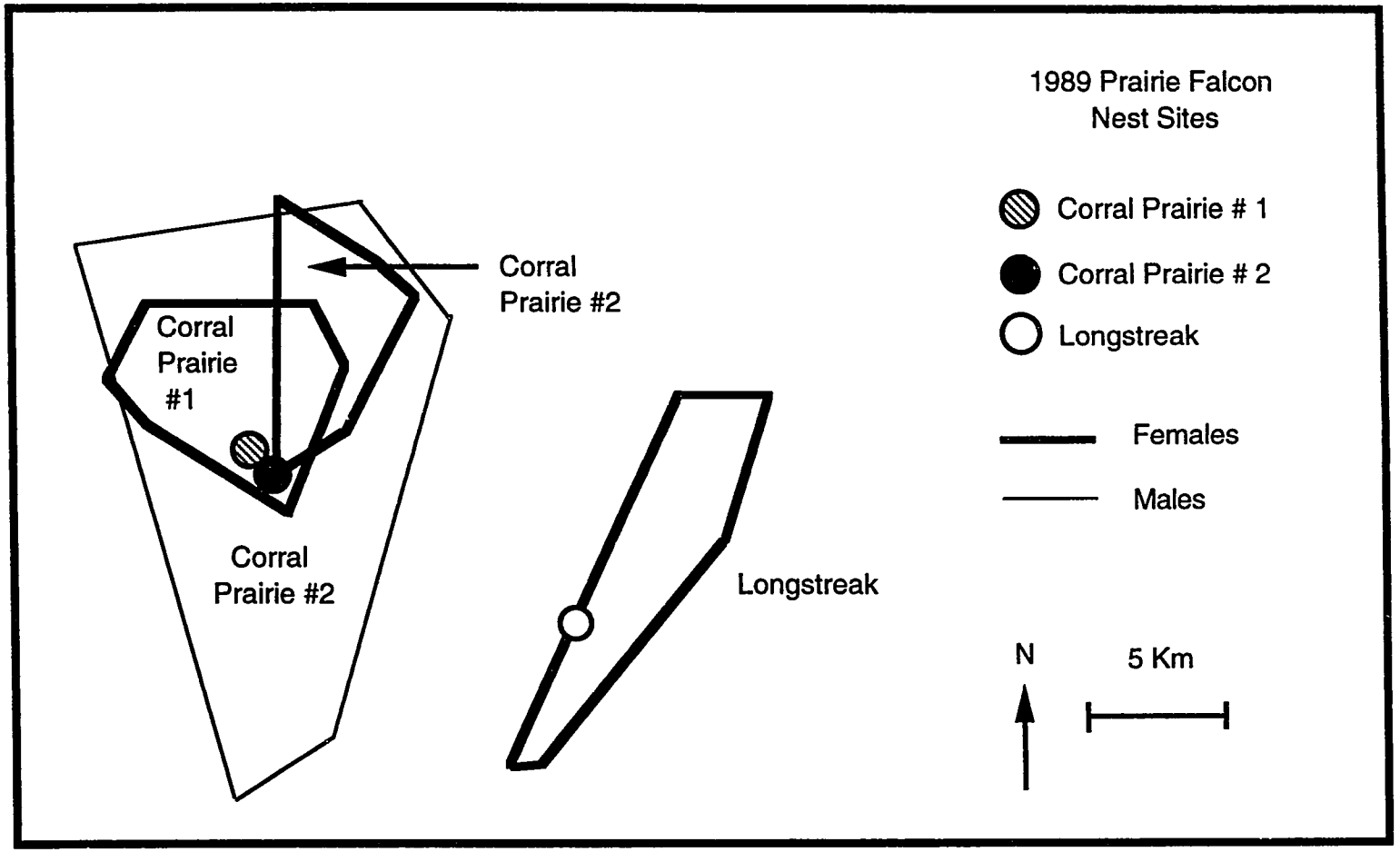

Figure 3-4a. Home ranges of 4 Prairie Falcons nesting in the Bow River Study Area in 1989.

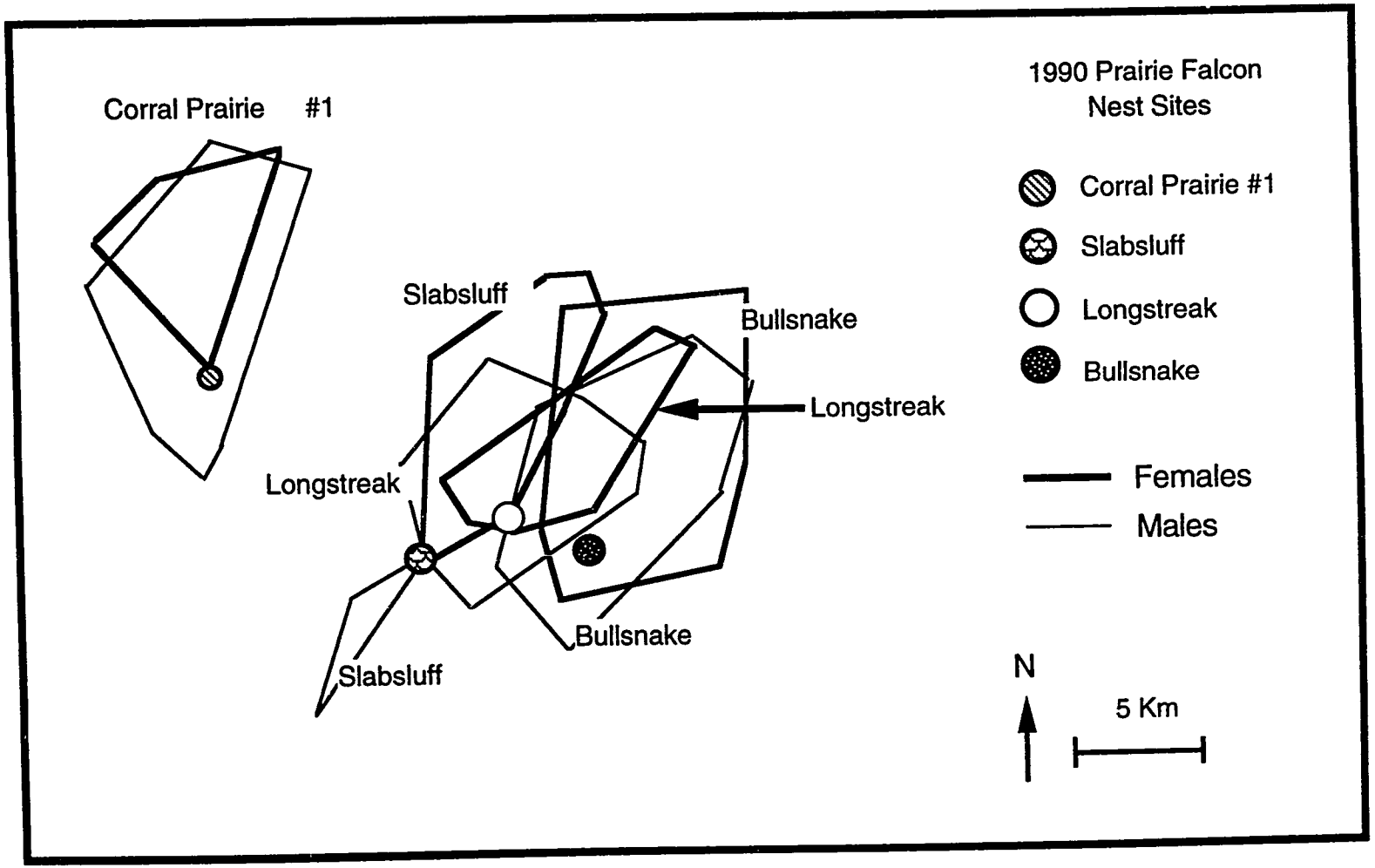

Figure 3-4b. Home ranges of 8 Prairie Falcons nesting in the Bow River Study Area in 1990.

Foraging Range

I recorded a total of 8 complete foraging trips, for 5 of 7 female falcons in 1989 and 1990. A bird was delivered to the nest (bird foraging trip) on one trip and ground squirrels on the remaining 7 (ground squirrel foraging trips). Thus, I do not describe foraging ranges of female falcons used when bird prey were delivered to the nest, nor compare this foraging trip to those when ground squirrels were delivered.

Since there were no differences among male falcons in maximum distances and sizes of foraging trips, I pooled all bird foraging trips (n=16) (Kruskal-Wallis ANOVAS; df=3, $p>0.05$), and all ground squirrel foraging trips (n=29) (Kruskal-Wallis; df=3, $p>0.05$). The mean maximum distance of bird foraging trips (4.30 km $\pm$ 0.72) of male falcons was significantly less than that of ground squirrel foraging trips (6.20 km $\pm$ 0.54; Mann-Whitney U=317, $p<0.05$). Similarly, the average size of bird foraging trips (753 ha $\pm$ 308) of male falcons was significantly smaller than that of ground squirrel foraging trips (1030 ha $\pm$ 215; Mann-Whitney U=231, $p<0.05$).

There were no differences among female falcons in maximum distances and sizes of ground squirrel foraging trips, so I pooled these trips (Kruskal-Wallis; df=3 $p>0.05$). The mean maximum distance of ground squirrel foraging trips of female falcons (7.46 km $\pm$ 1.60) did not differ significantly from that of male falcons (6.25 km $\pm$ 0.54; Mann-Whitney U=88, $p>0.05$). Similarly, average size of ground squirrel foraging trips of female falcons (1167.50 ha $\pm$ 412.79) was not significantly different than that of male falcons (1030.63 ha $\pm$ 215.96; Mann-Whitney U=85, $p>0.05$).

Size of foraging trips of male and female falcons was not correlated with the week of the nesting cycle ($r=0.15$, $p>0.05$, n=37; $r=0.30$, $p>0.05$, n=8, respectively).

Foraging ranges of adjacent nesting pairs (< 2 km apart) overlapped considerably, ranging from 22% to 100% (Fig 3-5a). Within pairs, foraging ranges of male and female falcons also overlapped, ranging from 33% to 93% (Fig. 3-5b). Ground squirrel foraging ranges were longer than wide and generally extended perpendicular to the nests (Fig. 3-5b). Bird foraging ranges varied in shape and size (Fig. 3-5b). Corral Prairie 1 and Bullsnake males exhibited relatively small bird foraging ranges that paralleled the river. Corral Prairie 2 and Longstreak male falcons, however, exhibited larger bird foraging ranges that extended over upland habitats.

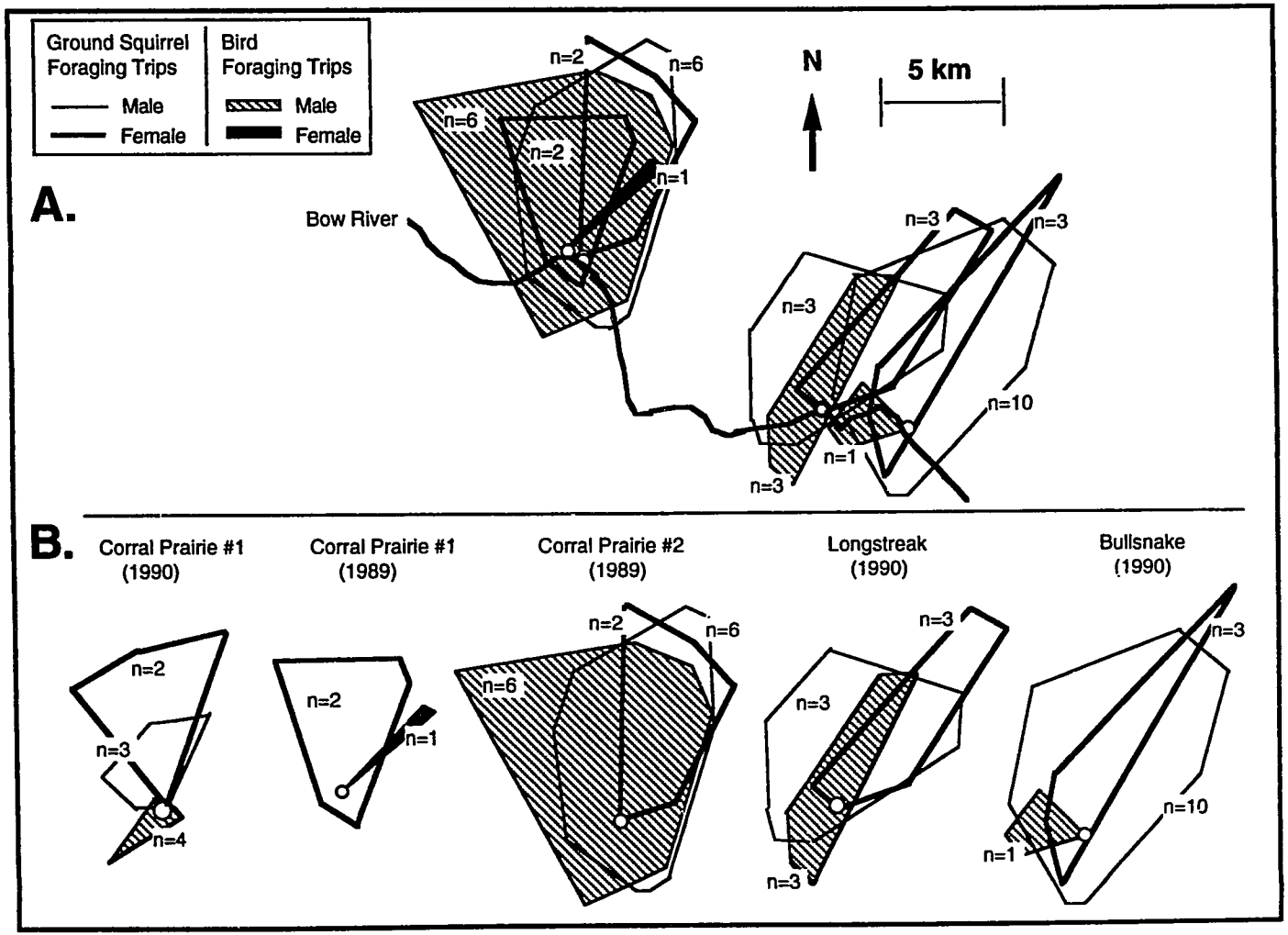

Figure 3-5. Foraging range locations of adjacent pairs of nesting Prairie Falcons (a), and male and female falcons within pairs (b). n = number of foraging trips used to estimate foraging range.

Core Areas of Use within Foraging Ranges

All 10 falcons exhibited core areas of use within ground squirrel foraging ranges, while only three falcons exhibited core areas of use within bird foraging ranges (Table 3-3). The number of core areas (1 km^2 grid cells) within ground squirrel foraging ranges and bird foraging ranges varied between falcons, ranging from 2 to 31 and 0 to 36, respectively (Table 3-3).

Core areas during ground squirrel foraging trips by adjacent nesting pairs of falcons overlapped, ranging from 19% to 25% (Fig. 3-6). Core areas during ground squirrel foraging trips by male and female falcons within pairs also overlapped, ranging from 0% to 19% (Fig. 3-7). Falcons that did exhibit core foraging areas when bird prey were delivered were not adjacent nesting pairs and were all males, therefore I did not evaluate overlap between pairs or among sexes for core areas used during bird foraging trips. Core areas used by male falcons during bird foraging trips overlapped 12 % with core areas they used during ground squirrel foraging trips (Fig. 3-8). Core areas used by male falcons during bird foraging trips overlapped less than 5 % with core areas used by female falcons during ground squirrel trips (Fig. 3-8).

Core areas used by male falcons during ground squirrel foraging trips occupied a smaller proportion of the foraging range (% foraging range) and received higher intensity of use than core areas used during bird foraging trips (Mann-Whitney $U=9.00$, $p<0.05$; Table 3-4). I excluded the Bullsnake male falcon from this analysis because the bird foraging range was based on only one foraging trip, and did not exhibit core areas of use. The percent of the foraging range within core areas and intensity of use of core areas did not differ significantly between male and female falcons during ground squirrel foraging trips (Mann-Whitney, $U=20$, $p>0.05$, $U=18$, $p>0.05$, respectively; Table 3-5).

Habitat Use

The proportions of habitat types within a 15 km radius of nest sites differed from the proportions within the home ranges (Fig. 3-9). The proportion of native range 1 (ground squirrel habitat) within home ranges was significantly greater than expected, based on availability within a 15 km radius of each nest (Wilcoxon paired sign-rank, $z=-1.82$, $p<0.05$). I found no differences ($p>0.05$) between the proportions of other habitat types within home ranges and their availability within a 15 km radius of the nest.

Table 3-3. Core areas of use within ground squirrel and bird foraging ranges used by nesting Prairie Falcons, southern Alberta, 1989-90. n = number of foraging trips used to determine foraging range and core areas.

		Ground Squirrel Foraging Trips			Bird Foraging Trips		
Falcon I.D.	Year	n	Foraging Range (ha)	Core Area (ha)	n	Foraging Range (ha)	Core Area(ha)
Male							
Bullsnake	1990	10	8386	3100	1	565	0
Longstreak	1990	3	4862	1200	3	1828	700
Corral Pr. 1	1990	3	1269	200	4	414	200
Corral Pr. 2	1989	6	6777	1800	6	8829	3600
Female							
Bullsnake	1990	3	2347	600	0	0	0
Longstreak	1990	3	2940	1400	0	0	0
Corral Pr. 1	1990	2	4048	700	0	0	0
Corral Pr. 1	1989	2	3172	900	1	14	0
Corral Pr. 2	1989	2	3200	1300	0	0	0
Longstreak	1989	1	600	300	0	0	0

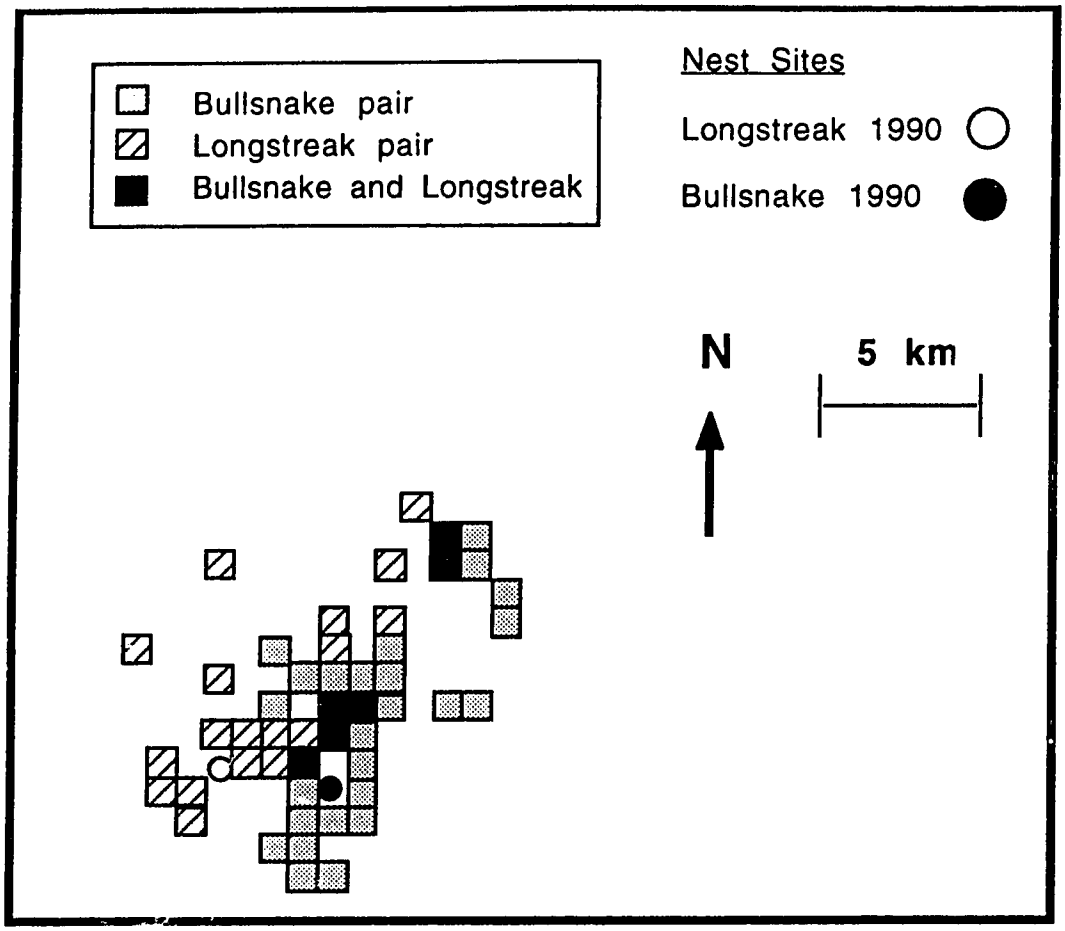

Figure 3-6. Overlap of core areas used during ground squirrel foraging trips, by 2 adjacent pairs of nesting Prairie Falcons in the Bow River Study Area in 1990.

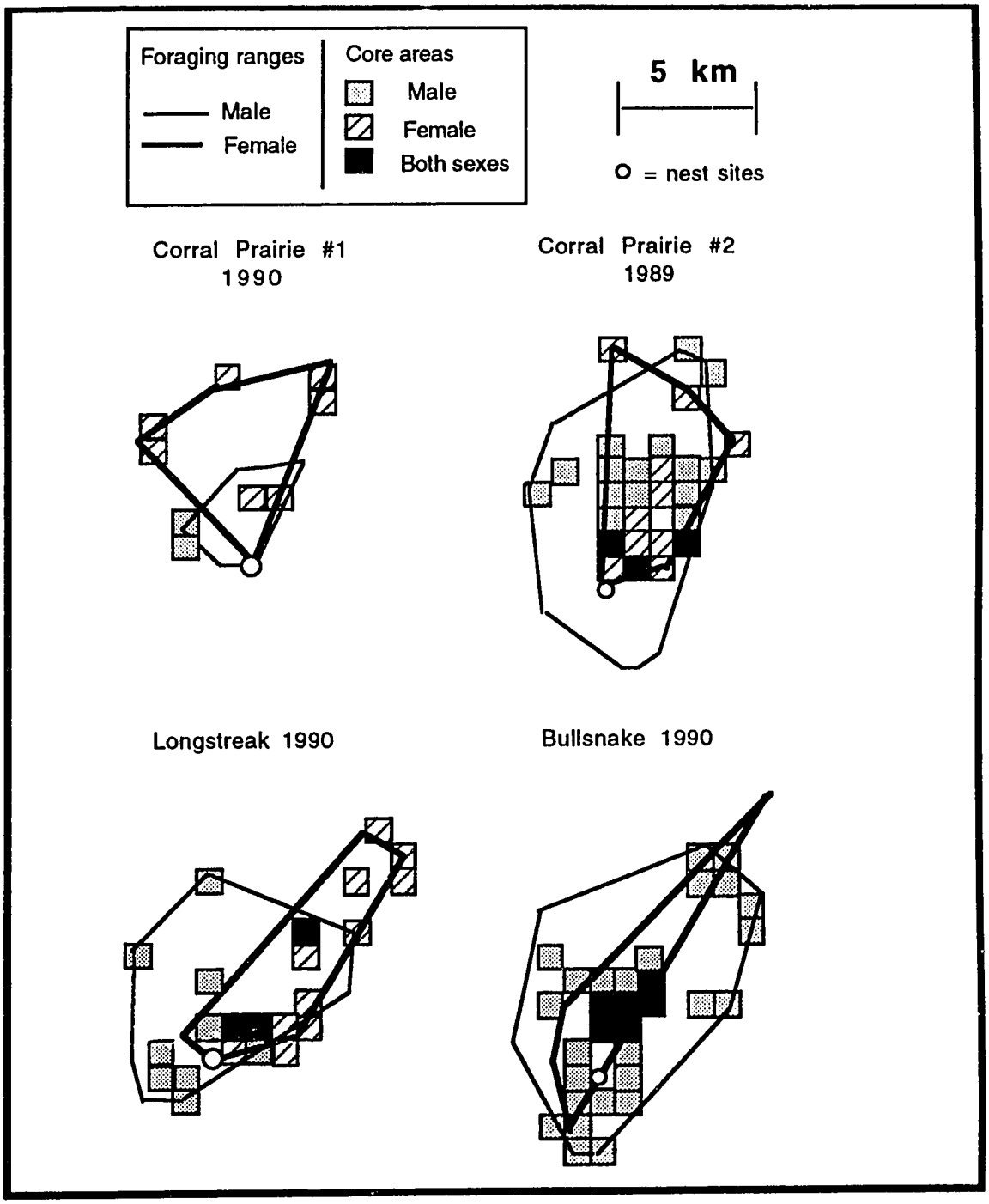

Figure 3-7. Core areas used by male and female Prairie Falcons during ground squirrel foraging trips in the Bow River Study Area.

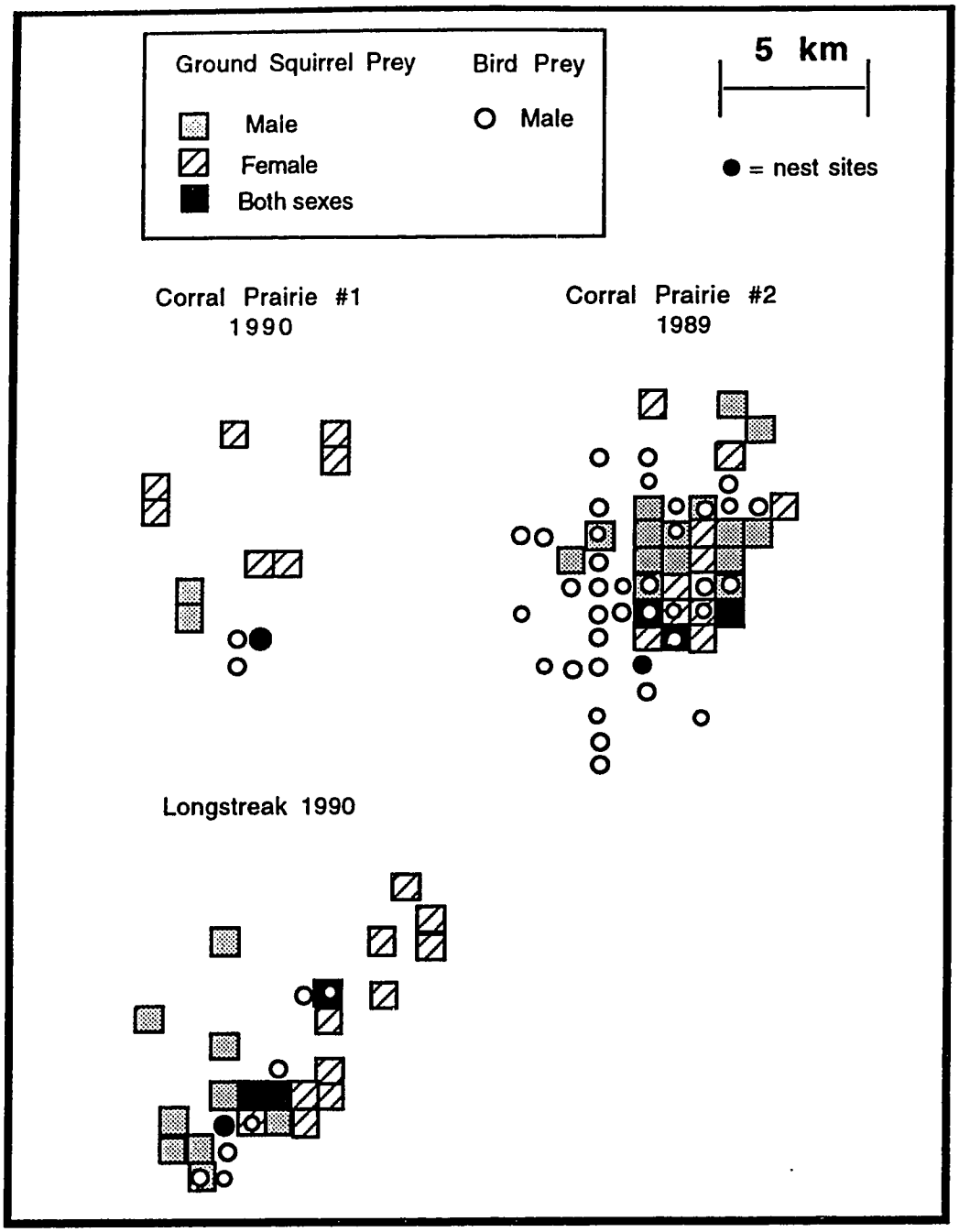

Figure 3-8. Overlap of core areas used during ground squirrel versus bird foraging trips by Prairie Falcons in the Bow River Study Area.

Table 3-4. Patterns of core area use within ground squirrel and bird foraging ranges used by male Prairie Falcons during the nesting season, southern Alberta, 1989-90. n = number of foraging trips used to determine foraging range and core areas.

Falcon I.D.	Year	n	Foraging Range (ha)	Core Area (ha)	% Foraging Range [a]	%Use [b]	Intensity [c]
Ground Squirrel Prey							
Longstreak	1990	3	4862	1200	25	84	3.36
Corral Pr. 1	1990	3	1269	200	16	68	4.25
Corral Pr. 2	1989	6	6777	1800	27	82	3.04
Bird Prey							
Longstreak	1990	3	1828	700	38	89	2.34
Corral Pr. 1	1990	4	414	200	48	52	1.08
Corral Pr. 2	1989	6	8829	3600	41	100	2.43

a % Foraging Range = percent of the foraging range within the core area

b % Use = percent of fixes (use) within the core areas.

c Intensity = %Use/% Foraging Range = a measure of the intensity of use within the core area

Table 3-5. Patterns of core area use within ground squirrel foraging ranges used by male and female Prairie Falcons during the nesting season, southern Alberta, 1989-90. n = number of foraging trips used to determine foraging range and core areas.

Falcon I.D.	Year	n	Foraging Range (ha)	Core Area (ha)	% Foraging Range [a]	%Use	Intensity [c]
Males							
Bullsnake	1990	10	8386	3100	37	87	2.35
Longstreak	1990	3	4862	1200	25	84	3.36
Corral Pr. 1	1990	3	1269	200	16	68	4.25
Corral Pr. 2	1989	6	6777	1800	27	82	3.04
Females							
Bullsnake	1990	3	2347	600	26	69	2.65
Longstreak	1990	3	2940	1400	48	100	2.08
Corral Pr. 1	1990	2	4048	700	35	100	5.80
Corral Pr. 1	1989	2	3172	900	28	100	3.57
Corral Pr. 2	1989	2	3200	1300	41	100	2.44
Longstreak	1989	1	600	300	50	100	2.00

a % Foraging Range = percent of the foraging range within the core area

b % Use = percent of fixes (use) within the core areas.

c Intensity = %Use/% Foraging Range = a measure of the intensity of use within the core area

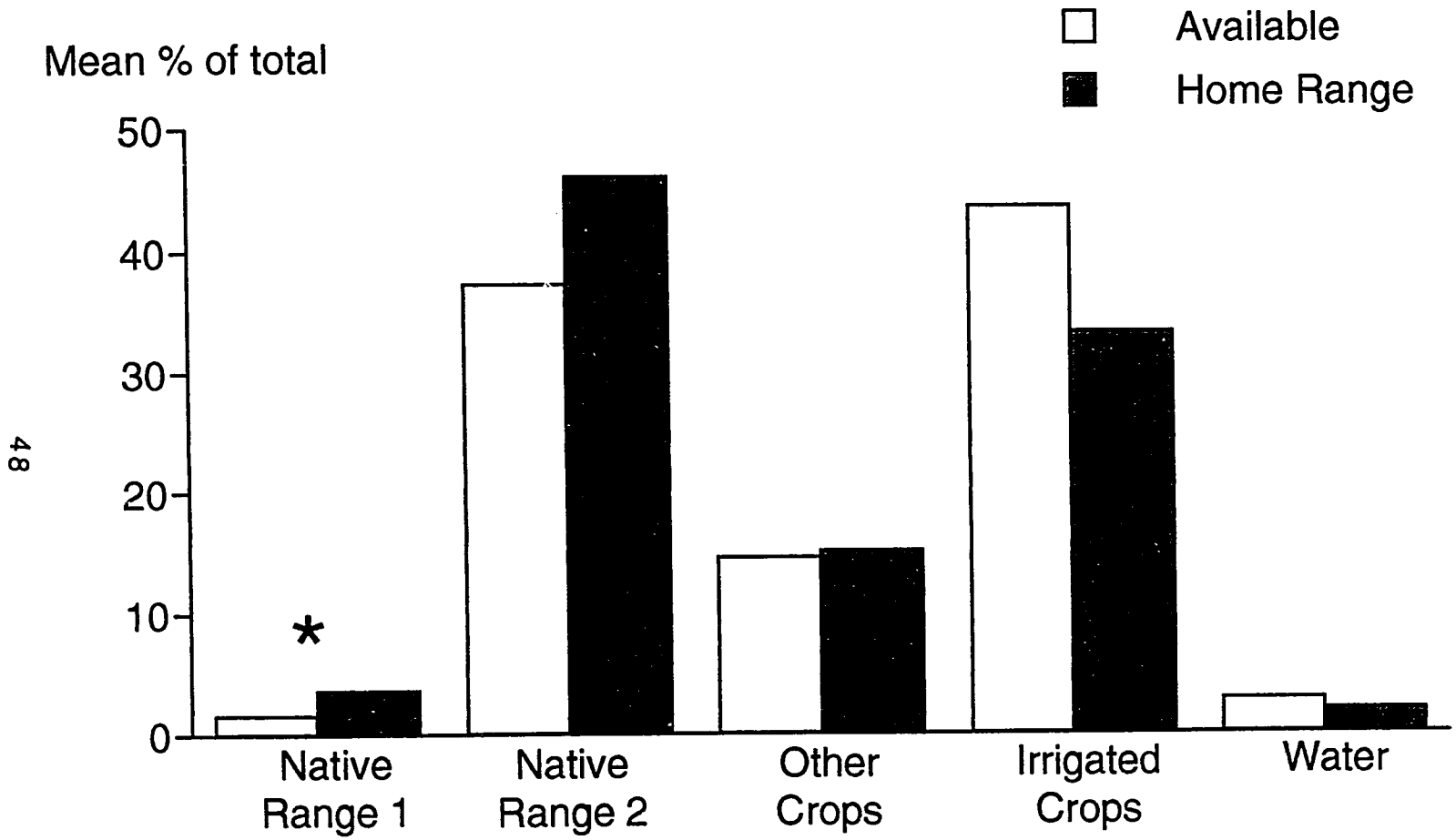

Figure 3-9. Proportions of habitat types within home ranges of 11 Prairie Falcons compared to availability.

Core areas used during ground squirrel foraging trips, exhibited a higher proportion of native range 1 (ground squirrel habitat) and lower proportion of irrigated crop than expected based on availability (Fig. 3-10; Wilcoxon paired sign-rank, $z=-2.70$, $p<0.05$, $z=-2.19$, $p<0.05$, respectively). The proportions of other habitat types within these core areas, were not significantly different than expected based on availability ($p>0.05$).

The proportions of habitat types within core areas, used during bird foraging trips, were not significantly different than expected based on availability (Fig. 3-11; $p>0.05$).

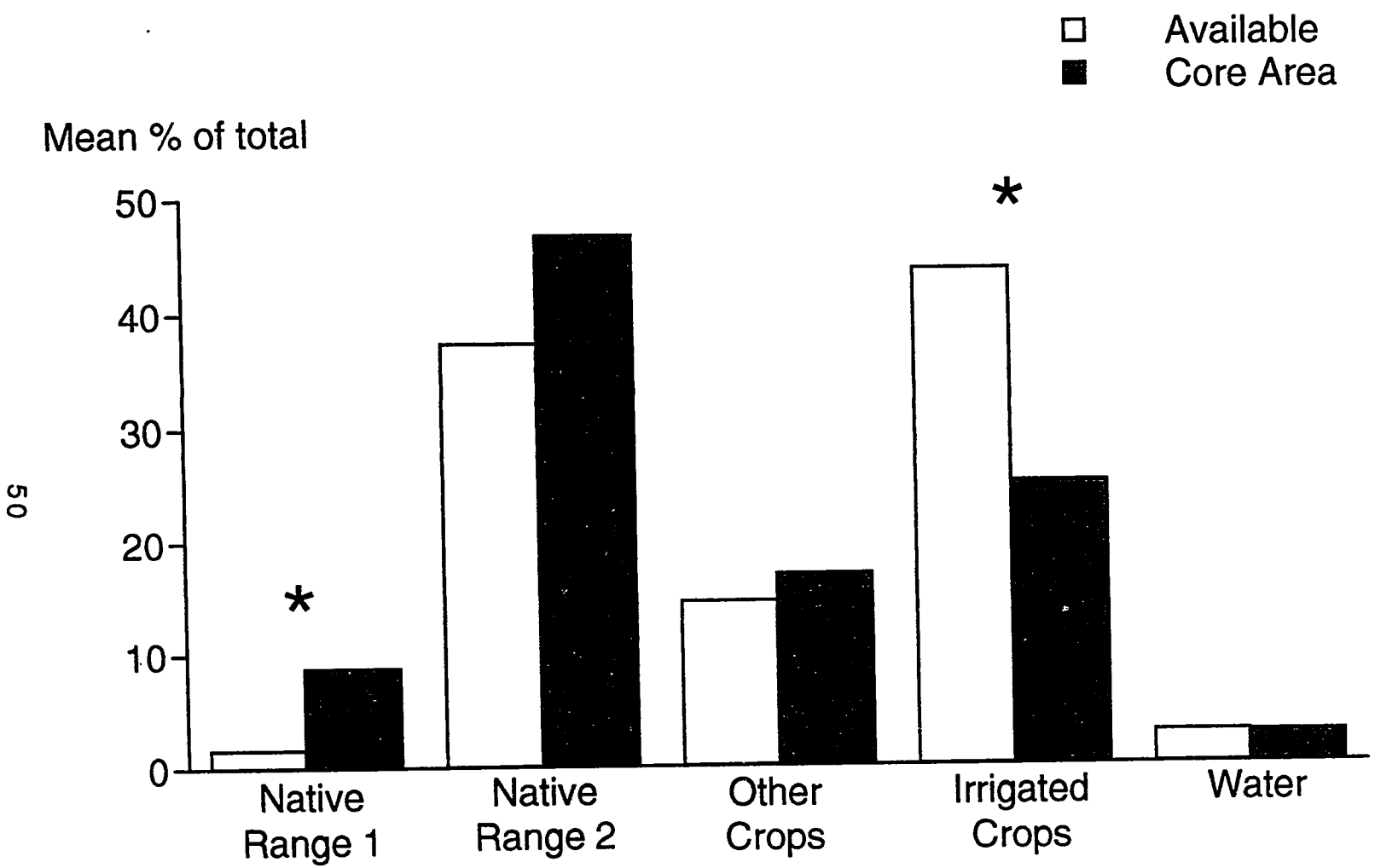

Figure 3-10. Proportions of habitat types within core areas used during ground squirrel foraging trips by 10 Prairie Falcons, compared to availability.

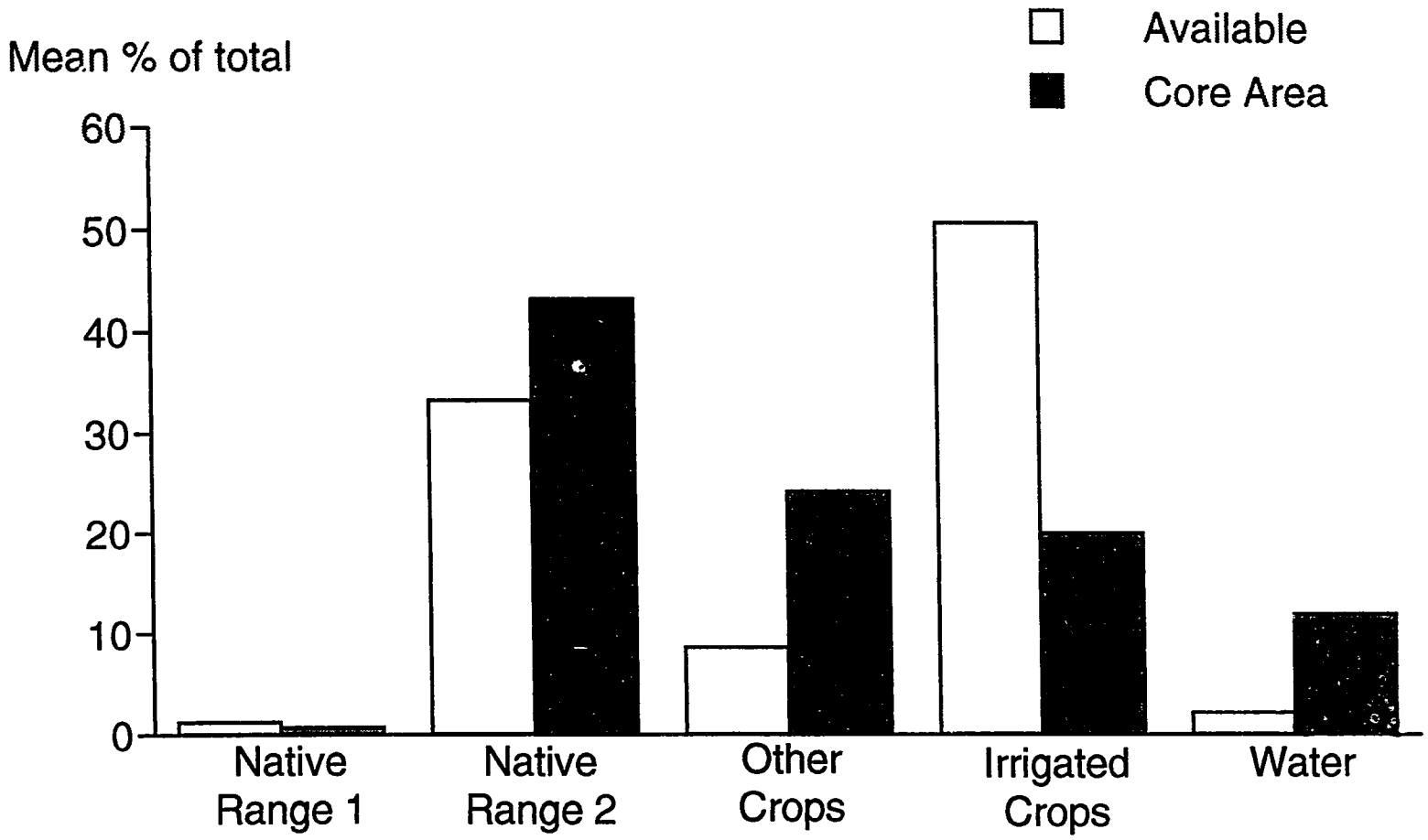

Figure 3-11. Proportions of habitat types within core areas used during bird foraging trips by three male Prairie Falcons, compared to availability.

3.4 DISCUSSION

The home range sizes documented in this study were within the range (4.25 km^2 to 389 km^2) documented for Prairie Falcons nesting in the United States (Craighead and Craighead 1956, Dunstan et al. 1978, Harmata et al. 1978, Haak 1982, Squires et al. 1993). Detailed comparisons among studies are difficult due to the variability in telemetry and data analysis techniques used (White and Garrot 1990). Differences in habitat types, and prey characteristics (distribution and availability) may also affect home range sizes (Squires et al. 1993).

In this study, comparisons of home range sizes among falcons are limited by the positive correlation between home range size and sample size. Cumulative home range size of individual falcons did not clearly reach an asymptote, but continued to increase as sample size (i.e. number of fixes) increased. Therefore, it is not possible to conclude that male falcons actually use larger home ranges than females, because more locations of males were obtained than female locations. In addition, home ranges reported in this study for both males and females must be recognized as minimum estimates of the size and shape of areas used during the nesting season.

Few authors have addressed the problems associated with home range analysis in patchy environments, and there is little guidance in the literature (MacDonald et al. 1980, Schoener 1981, Anderson 1982, Cockburn 1984, Spencer and Barrett 1984). Home range estimates based on convex polygons include large areas of land that are not used by falcons. This is due to the extreme patchiness of the prairie landscape and the absence of suitable prey in some habitat types. My results clearly demonstrated that the area within a home range is not uniformly utilized by falcons.

Even though home ranges are not uniformly utilized, they do represent prior selection by falcons of a particular area (White and Garrot1990). In my study, falcons hunted primarily north of the river, ranging up to 20 km from the nest. The proportion of native range 1 (uncultivated land associated with ground squirrel colonies) was significantly greater in home range areas than within a 15 km radius area around each nest site. This suggests that the pattern of selection of home range areas north of the river may be partially due to the availability of ground squirrel prey. We did not assess relationships between the characteristics of native range 1 (patch sizes, juxtaposition) and ground squirrel densities. We recognize, therefore, that a higher proportion of native range 1 habitat is not a

direct indication of higher ground squirrel densities.

Squires et al. (1993) concluded that distance of a particular habitat type from the nest site was the most important predictor of habitat use. Habitats that were closer to the nest sites were preferred, and falcons typically foraged within 10 km of their nests. In my study, foraging trips ranged from approximately 2 km to 20 km, but both male and female falcons typically foraged within 15 km of the nest when ground squirrel prey were delivered. During such trips, no differences in mean maximum foraging distances from the nest were detected between the sexes. However, when male falcons delivered bird prey to the nest, foraging trips were significantly shorter than when ground squirrel prey was delivered. Thus, when hunting near the nest it may be profitable for males to deliver smaller prey, but when hunting greater distances only large prey are delivered because of the energetic costs incurred as flying time increased (Newton 1979).

This study found no evidence that Prairie Falcons occupy exclusive foraging territories during the breeding season. Home ranges, foraging ranges and core areas used while hunting ground squirrel prey all overlapped between adjacent pairs. Some pairs nested within 1 km of each other, and home and foraging ranges overlapped considerably near nest sites. Bird foraging trips, which usually paralleled the river, often passed near occupied nest sites of other nesting Prairie Falcons and Golden Eagles (Aquila chrysaetos). We seldom witnessed territorial behaviour between nesting conspecifics. These results are consistent with a study in northern California, where foraging areas of nesting Prairie Falcons overlapped and falcons foraged within 0.8 km of other falcons nest sites with no apparent conflicts (Haak 1982). However, Craighead and Craighead (1969) report nesting pairs of Prairie Falcons usually maintain hunting ranges distinct from those of other nesting falcons and that ranges do not overlap in the vicinity of nests.

For several species of raptors it has been reported that males and female differ in habitat use (Koplin 1973, Opdam 1975, Marquiss and Newton 1982a,b). Opdam (1975) and Marquiss and Newton (1982a, b) related this to differences in body size, suggesting that segregation was caused by preferences for different kinds of prey which may be most available in different habitats. Prairie Falcons in the Bow River Study Area appear to use different habitats for foraging during the last half of the nesting cycle. During the last 3 weeks of the nesting cycle, male falcons primarily delivered bird prey to the nest site, while the female delivered ground squirrel

prey. Because foraging trips that resulted in the delivery of ground squirrel prey to the nest usually extended perpendicular to the river, and foraging trips that resulted in delivery of bird prey usually paralleled the river, males and females used different habitats during this period. Further, core areas used when ground squirrel prey was delivered by females rarely overlapped with core areas used when bird prey was delivered by males.

During foraging trips that resulted in ground squirrel delivery, Prairie Falcons in my study appeared to prefer to forage in areas that contained higher proportions of native range 1 (ground squirrel habitat) and lower proportions of irrigated crop, relative to their availability. Native range 1 is unbroken prairie grassland, similar in vegetative characteristics to native range 2. Patches of native range 1, almost always contained Richardson's Ground Squirrel colonies, while patches of native range 2 did not. The characteristics that distinguish native range 1 (ground squirrel habitat) from native range 2 are still not understood. Further, information about availability of ground squirrels in different sized patches is poor. If densities of ground squirrels increase with patch size, then falcons foraging in larger patches of ground squirrel habitat should have higher probability of encountering suitable prey without having to fly some distance to another patch (Weins 1989).

Individual foraging trips by falcons that resulted in the delivery of bird prey appear to be associated with riparian and native range habitats along the Bow River, but the proportions of habitat types within core areas were not different from their availability. The proportion of water within core foraging areas used when bird prey were delivered was probably underestimated, because irrigation canals were not identified on the GIS maps. Irrigation canals are commonly associated with undisturbed habitats and dense vegetation adjacent to the canals (i.e. shrubs). Thus, riparian habitats, including irrigation canals, potentially provide important foraging habitat for falcons.

In summary, Prairie Falcons nesting in the Bow River River Study Area appeared to select home ranges with significantly higher proportions of native range 1 (ground squirrel habitat). Home ranges, foraging ranges, and core areas overlapped between nesting pairs and within pairs. Male falcons hunted closer to the nest when bird prey was delivered to the nest than when ground squirrel prey was delivered. Core areas used during ground squirrel foraging trips had higher proportions of native range 1 and lower proportions of irrigated crop than expected based on availability within 15 km of

nest sites. Areas used when bird prey was delivered to the nest appear to be associated with riparian habitats, but no significance was detected.

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4.0 SUMMARY

4.1 Summary of Results

Richardson's Ground Squirrels were the primary prey of Prairie Falcons nesting along the Bow River in southern Alberta, while waterfowl and songbirds were secondary prey. A comparison of techniques used to determine diet composition of nesting Prairie Falcons showed that direct observation, supplemented with analysis of prey remains and pellets, provides the most complete estimate of the diet of nesting Prairie Falcons. Direct observation provides the most accurate representation of the proportions of prey types being delivered to the nests. It also provides useful information on prey delivery rates, and permits comparisons between the sexes. Pellets and prey remains provide information about age, sex, and/or species of prey, but do not accurately represent proportions of prey types. Pellets are useful for identifying very small prey, such as microtines, which are eaten whole by falcons and are not represented in samples of prey remains.

Food delivery was not shared equally between both members of each pair. Male prey delivery rates exceeded female prey delivery rates throughout the nesting cycle. During incubation and the first 2 weeks of brood rearing, males provided almost all the prey to the female and young, delivering primarily Richardson's Ground Squirrels. During the third week of brood rearing, females increased their prey delivery rates, delivering primarily ground squirrels. Finally, during the last half of the nesting cycle, the number of bird prey delivered by male falcons increased, while female falcons continued to deliver primarily ground squirrel prey.

Foraging trips that resulted in the delivery of ground squirrel prey differed significantly from foraging trips that resulted in the delivery of bird prey. Ground squirrel foraging trips were longer in distance and duration, and covered larger areas than bird foraging trips. Core areas used during bird foraging trips were used less intensively than core areas used during ground squirrel foraging trips. Also, core areas used when ground squirrel prey were delivered exhibited higher proportions of native range 1 (ground squirrel habitat) and lower proportions of irrigated crop than expected based on availability. Almost all patches of native range 1 contained Richardson's Ground Squirrel colonies, while patches of native range 2 did not. The proportions of habitat types in core

areas used during bird foraging trips did not differ from their availability.

Minimum home range sizes, based on convex polygons, ranged from 31 km^2 to 192 km^2, and extended up to 20 km from nest sites. Home ranges usually extended north of the river and included higher proportions of native range 1 (ground squirrel habitat) than expected based on availability. Therefore, availability of ground squirrels appears to play a part in determining the distribution of Prairie Falcon home ranges.

4.2 Management Implications

Diet, foraging strategies, and habitat use recorded in this study are similar to those from Prairie Falcon studies elsewhere in North America. It is likely, therefore, that findings from this study are applicable to land use and wildlife management decisions concerning Prairie Falcons elsewhere in Alberta.

The distribution of nesting Prairie Falcons is usually governed by 2 factors: 1) availability of nest sites, and 2) availability of food. Successful management requires a focus on both factors. Protecting nest sites or increasing nest site availability by creating artificial cavities along cliffs is often easier than protecting habitats of prey. Nest sites, however, are only occupied when foraging areas are also available.

Biologists and land managers should focus on maintaining foraging areas within close proximity to prairie rivers that contain potential Prairie Falcon nest sites. Foraging areas include ground squirrel colonies, wetlands for waterfowl, and native range for songbirds.

In this study, the availability of native range 1 (ground squirrel habitat) within 15 km of nest sites was less than 5 %. Prairie Falcons showed significant preference for this habitat, ground squirrels were their primary prey. Therefore, protection of ground squirrel colonies within proximity to Prairie Falcon nest sites is very important.

The average foraging distance when ground squirrel prey was delivered was approximately 6 km, and when bird prey was delivered was 4 km. These distances can be used as guidelines for determining availability of foraging habitat within proximity to nest sites.

4.3 Recommendations for Future Research

The relationships between Prairie Falcon populations and their prey make it difficult to effectively manage falcons without also managing their prey. Our ignorance of prey species' habitat requirements and population biology makes management of Prairie Falcon populations difficult. There is a strong need for cooperative research among raptor biologists, range ecologists and scientists studying prey population dynamics. Research objectives should include:

1) determine habitat requirements of prey species, especially Richardson's Ground Squirrels,

2) examine the effects of habitat patch size and distribution on ground squirrel population dynamics, and

3) examine the relationships between prey habitat patch size and distribution on Prairie Falcon foraging strategies.

Lastly, biologists need to make a commitment to monitoring populations of raptors and their prey, through a review of current monitoring procedures and implementation of standardized surveys. In addition to monitoring raptor population size, monitoring reproductive success should take place, in order to more clearly assess the potential effects of changes in prey densities and land use.