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BREEDING BIOLOGY AND PREY SELECTION OF FERRUGINOUS HAWKS IN NORTHWESTERN SOUTH DAKOTA

by

CHARLES L. BLAIR

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Wildlife and Fisheries Sciences
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1978

BREEDING BIOLOGY AND PREY SELECTION OF
FERRUGINOUS HAWKS IN NORTHWESTERN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Frank Schitoskey, Jr. Date
Thesis Advisor

Charles G. Scalet Date
Head, Dept. of Wildlife and
Fisheries Sciences

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BREEDING BIOLOGY AND PREY SELECTION OF FERRUGINOUS HAWKS IN NORTHWESTERN SOUTH DAKOTA

Abstract

CHARLES L. BLAIR

A study of the breeding biology and prey selection of ferruginous hawks (Buteo regalis) was conducted in northwestern South Dakota during 1976 and 1977. Twenty four pairs were located in 1976 and 18 pairs attempted to nest; 17 pairs located in 1977 attempted to nest. The ecological density of breeding pairs was approximately one per 100 km^2. Young fledged per nesting attempt averaged 1.89 in 1976 and 2.29 in 1977. All but one nest were located in unbroken, lightly grazed prairie, and all were situated on hills, buttes, or river cutbanks. General nest orientation was toward the south and west. Six hundred ninety food items were identified from regurgitated pellets and prey remains collected at the nest sites. Mammals composed 94 percent, birds 5 percent, and reptiles 1 percent of prey biomass; white-tailed jackrabbits (Lepus townsendi) and thirteen-lined ground squirrels (Citellus tridecemlineatus) were the most important items. Movements of six radio-tagged juveniles were monitored from the time of fledging until departure from the study area. The juveniles usually expanded the size of their utilized areas during each successive week after fledging. Most ferruginous hawks had left the study area by mid-September.

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INTRODUCTION

The ferruginous hawk (Buteo regalis) is the largest of the North American Buteos. It occurs throughout most of the western United States and breeds from Alberta, Canada, to west Texas and from Washington to Arizona. Recent studies by Weston (1969) in Utah, Olendorff (1973) in Colorado, and Howard (1975) in Utah and Idaho have produced information about the breeding biology of the ferruginous hawk in those areas. Lokemoen and Duebbert (1976) studied this species in northcentral South Dakota, an area dominated by cropland and tame hay pasture. To date no work has dealt with either the nesting ecology or the current status of this species on the open prairies and rangeland of the northern Great Plains.

The study area has supported a livestock economy for the past 125 years (Westin et al. 1967). Recently, mineral interests have been searching for coal, oil, gas, and uranium in the study area. Development associated with mineral extraction and an increase in small grain farming will result in increased human activity in what are now relatively remote or undisturbed parts of the study area.

Ferruginous hawks were listed as status "undetermined" by the U.S. Department of the Interior (U.S.D.I. 1968). The National Audubon Society has placed the ferruginous hawk on the Blue List which includes those species that "are suffering population declines or range diminution in all or parts of their range, but are not now of sufficient rarity to be considered endangered" (Arbib 1972).

Ferruginous hawks appear to be sensitive to human activity in the vicinity of their nests. They will often abandon a nest if even a single visit is made to it before the eggs have hatched (Davy 1930, Olendorff 1973, Howard and Powers 1973, Smith and Murphy 1973, Howard 1975).

My objectives were: (1) to determine the population level of the ferruginous hawk in northwestern South Dakota; (2) to determine the ecological density of nesting pairs based on the number of nesting pairs and the amount of preferred habitat available; (3) to determine the reproductive success (clutch size, hatching rate, and fledging rate); (4) to document the food consumption of both young and nesting adult ferruginous hawks; (5) to estimate the proportions of different types of habitat associated with each hunting territory; and (6) to determine the post fledging activity of juveniles.

STUDY AREA

The study area encompassed approximately 7000 km^2 area in the northwest corner of South Dakota and included all of Harding County (Fig. 1). The area has a mid-continental climate with long, cold winters and short, warm summers (Spuhler et al. 1971). The average annual temperature is 9 C, the mean January temperature is -9 C and the mean July temperature is 22 C. The area is semi-arid with an average of 33 cm of precipitation per year. The prevailing winds are from the north to northwest during winter and from the south to southwest during summer. Average wind speed is 18 km per hour. Evaporation exceeds rainfall with 80 percent of the evaporation occurring between May and October (Spuhler et al. 1971).

Harding County was not covered during the last glacial period; as a result, the drainage pattern is well developed. Westin et al. (1967) called this area the Northern Plateau region of South Dakota. They described it as a series of rolling to undulating plateaus and isolated buttes drained by the Grand and Moreau Rivers flowing toward the east and the Little Missouri River flowing to the north. A number of buttes outcrop over part of the area. These consist of sands and clays and represent deposits laid down by wind and streams on recently exposed ocean bottom after the sea withdrew during the Cretaceous period (Rothrock 1937). Several extensive areas of elevated table land composed of sandstone are remnants of the former northward drainage of the area (Baker 1952).

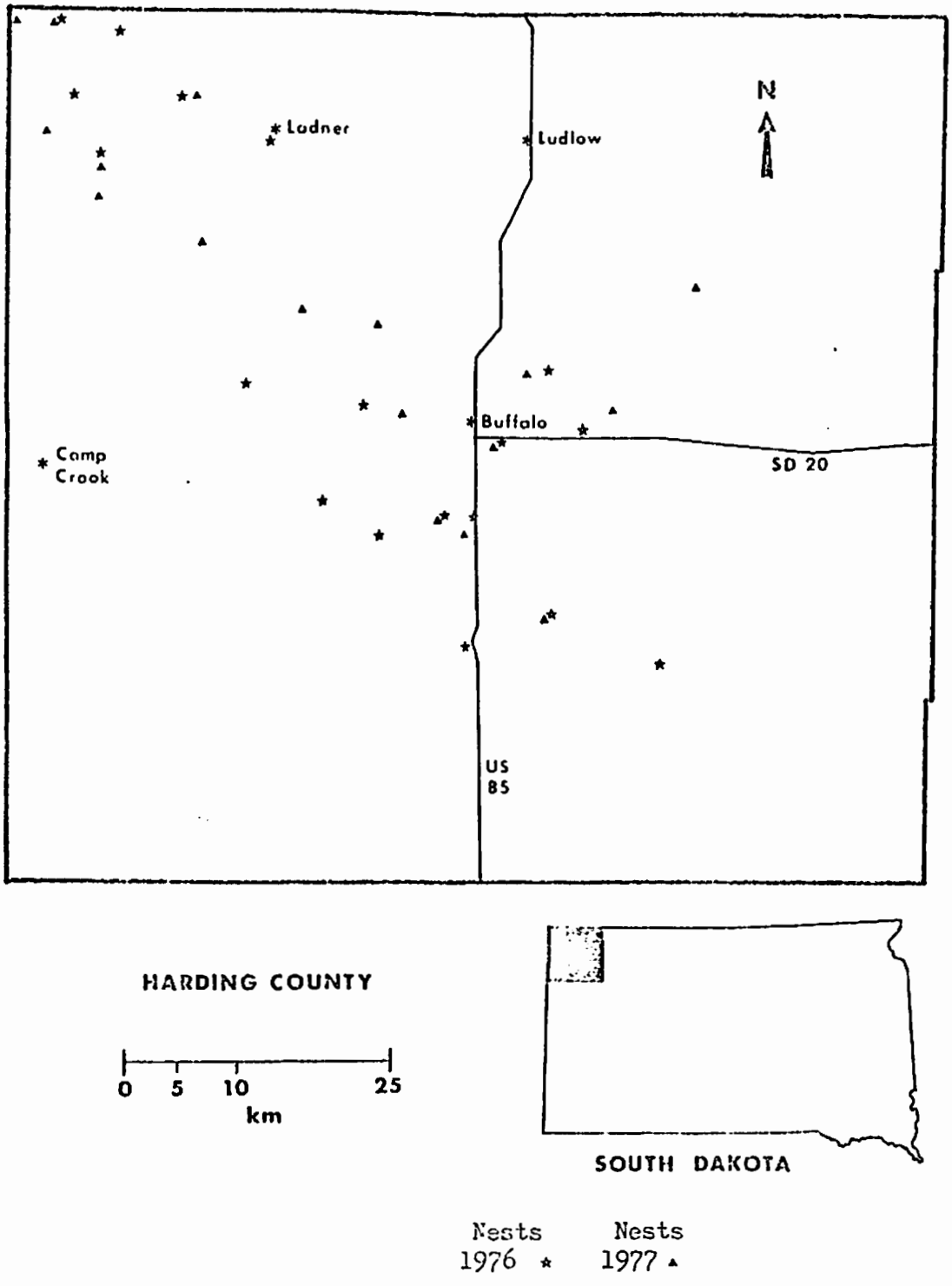


Fig. 1. Harding county study area and locations of active ferruginous hawk nests in 1976 and 1977.

Approximately 85 percent of the county is rangeland dominated by wheatgrass (Agropyron spp.) and needle grass (Stipa comata). Sagebrush (Artemesia spp.) occurs throughout the area and is widespread in the western third of the county. Cropland, mostly small grain, composes 9 percent of the area; pastureland and tame hay composes 3 percent. The remaining 2 percent is wooded. Elevated table lands are dominated by ponderosa pine (Pinus ponderosa) savannah, while riparian areas and ravines are dominated by green ash (Fraxinus pennsylvanicus), willow (Salix spp.), and Siberian elm (Ulmus pumila) (U.S.D.A. 1976a).

METHODS

North American ferruginous hawks winter in the southcentral and southwestern parts of the United States and northern Mexico. Birds breeding in the study area return in late March. Active nests were located during aerial surveys conducted from a fixed wing aircraft flying at altitudes of 150 to 175 m. Additional nests were located during ground searches conducted from roads. Nest locations were marked on a U.S. Forest Service map and assigned a number.

Ferruginous hawks will readily abandon their nest if disturbed during the incubation period (Olendorff 1973, Howard and Powers 1973, Smith and Murphy 1973, Howard 1975); however, the possibility of adult nest desertion is reduced once hatching occurs (Snow 1974). Initial nest visits were postponed until after the incubation period. Nests were approached indirectly by walking beyond the nest at a distance of approximately 50 m; the path was retraced to a point directly in front of the nest, from this point the nest was approached directly. The opposite procedure was used upon leaving the nest and the route was sprinkled with napthalene crystals to reduce the possibility of mammalian predation of nests (Ray 1968, Hammerstrom 1970).

During initial nest visits, clutch size was determined from the number of young and the number of remaining unhatched eggs. Productivity was estimated by the number of young fledged per total pairs present, per nesting attempt, and per successful nest. A

nest attempt was defined as the presence of at least one egg; a successful nest was one from which one or more young was fledged.

Crude density was determined by dividing the total area by the number of pairs present. Ecological density (Odum 1971) was determined by dividing the area of the townships in which pairs were found by the total number of occupied territories and successful nests.

Nest sites were classed according to type, vegetative cover, height, aspect, and surrounding vegetation. Periodic visits were made to all nests to determine weight and survival of nestlings. At the age of 30 to 35 days, nestlings were banded with U.S. Fish and Wildlife Service lock-on leg bands. In 1976 nestlings were fitted with color coded, numbered, patagial wing markers. The diameter of the flexed hallux of the right foot was measured at this time for possible use in sexing nestlings (Howard 1975).

Sexual dimorphism in which females are larger than males is common in most species of raptors (Brown and Amadon 1968). Weights and flexed hallux measurements of 27 female and 31 male ferruginous hawks were recorded after they had reached an age of 30 days, at which point development is approximately 90 percent complete. These measurements were used to sex the unfledged nestlings.

During nest visits, all regurgitated pellets and prey remains found in and around the nest were collected. Pellets were cataloged, air dried, and analyzed at a later date. Teeth, bones, hair, and

feathers were identified by comparison with a reference collection developed from animals trapped on the study area.

Fourteen nests situated in elevated areas were subject to frequent high winds which resulted in loss of pellets. A circular fence 10 cm high with a 2 m radius was placed around these nests. Pellets were blown against the fence and remained there for collection. The presence of these fences did not interfere with normal activity at the nest.

Glading et al. (1943) evaluated raptor pellets as indicators of food habits and concluded that it was difficult to assess numbers of individual prey represented in hawk pellets. However, Fitch et al. (1946), reinterpreting data from Glading et al. (1943), found that each pellet occurrence corresponded to one individual prey item. I assumed that the occurrence of a particular species in a pellet constituted one individual of that species unless numbers of teeth and bones indicated otherwise. Since most pellets collected were those from young birds, I also assumed that the composition of prey brought to the young reflected the adult diet. Percent frequency of occurrence was calculated for all prey species, and percent biomass was calculated for the major prey items using average body weights of birds and mammals (Luttich et al. 1970). Mammalian and avian weights were obtained from population investigations in the study area and from the literature (Hall and Kelson 1959, Ort and Grossenheider 1976). Mean weights of juveniles were

assumed to be one-half of adult weight except where field studies provided more precise measurement (Luttich et al. 1970).

During 1977 radio transmitters were placed on six fledged nestlings, two from each of three nests. The transmitters were used to determine the post fledging activities. Transmitters were attached with a backpack harness (Dunstan 1972) and weighed 25 g, approximately 1.5 percent of the weight of the smallest juvenile male. Harnesses were sewn with different strength thread so that the upper strap would fail first, allowing the transmitter to drop off the bird without causing injury.

Locations were obtained by triangulation from two semi-permanent towers within range of each nest. Antenna masts were 6 m high and were located approximately 1100 m apart. Actual antenna placement in relation to the nests was determined by two factors. Placement of antennas on hilltops was essential for maximizing the effective range of the radio transmitters. Selection of sites which would provide the greatest angular accuracy in relation to the nests was also desirable. Due to the terrain surrounding the nests selected for the telemetry study it was impossible to optimize both factors. It was not known at the beginning of the study in which directions the juveniles would expand their ranges, therefore antenna sites were selected which would provide reasonable range and yet maintain acceptable angles for obtaining signal locations. This resulted in slight elongation of the weekly location plots of the radio-tagged birds. Each tower consisted of a pair of four

element yagi antennas stacked so that a distinct null signal occurred when the antennas were directly facing a bird. Locations were taken every 10 to 15 minutes, depending on activity, on days when weather permitted. The two antenna operators were in radio contact so that directions could be taken simultaneously.

Locations were plotted by hand and maximum area was delineated by the method proposed by Odum and Kuenzler (1955). The maximum area was determined by connecting the outermost location with straight lines. Utilized area was determined after the extreme 5 percent of points were eliminated and the new outermost points were connected forming a straight sided polygon. Locations were plotted weekly for size and area of utilization comparisons. Size of the utilized areas was determined by measuring the respective polygons with a planimeter.

RESULTS AND DISCUSSION

Breeding Season Chronology

Ferruginous hawks were first observed on the study area in late March in both years. The first courtship and nesting activity was observed during the first week of April. Exact dates of egg laying were not known because initial nest visits were delayed until mid-May. Assuming an incubation period of 35 days (Olendorff 1973), the median dates of egg laying were 21 April in 1976 and 19 April in 1977. Incubation lasted approximately 35 days and 40 days elapsed from hatching to fledging (Table 1).

Ferruginous hawks in Utah arrived in the nesting area in early March and began laying in late March (Smith and Murphy 1973, Howard 1975). In Colorado breeding activity began somewhat later than in Utah and was extended over a longer period (Olendorff 1973). Breeding territories were established at a later date in northwestern South Dakota than in Colorado or Utah. The time elapsed between hatching and fledging was shorter in Harding County than in Colorado or Utah resulting in fewer days on the nest for the nestlings and an overall shorter breeding season.

Nest Site Selection

In Harding County all but five nests were located within a narrow strip approximately 25 km wide extending from northwest

Table 1. Breeding chronology of ferruginous hawks in Harding County, South Dakota.

	1976	1977
First observation of adults	24 March	27 March
First courtship displays observed	4 April	5 April
Earliest laying date	13 April	15 April
Median laying date	21 April	19 April
Latest laying date	28 April	22 April
Earliest hatching date	17 May	20 May
Median hatching date	25 May	24 May
Latest hatching date	1 June	27 May
Earliest fledging date	25 June	25 June
Latest fledging date	12 July	10 July
Average number of days young were in the nest	39	41
Length of breeding season	99	95

to southeast through the center of the county (Fig. 1). This band corresponded roughly with the greatest concentration of buttes and hills used by ferruginous hawks as nesting structures. Land use in the northeast portion of the county was dominated by small grain farming which rendered many areas unsuitable for nesting ferruginous hawks, while in the southwest portion of the county the terrain lacked the types of structures most frequently selected as nest sites.

With one exception, all nests were located in unbroken, ungrazed or lightly grazed prairie or in small badland areas surrounded by prairie. One nest in 1976 was situated adjacent to a lightly traveled county road, surrounded by alfalfa, and was unsuccessful.

Ferruginous hawks in Harding County utilized five distinct nesting situations; river bed mounds, river cutbanks, low hills, mud buttes, and high vegetated hills. Twenty-one of the active nests (55 percent) were located on unvegetated mud buttes (Table 2). Height of the nesting structures above the surrounding prairie ranged from 0 to 25 m with a mean of 6.1 m in 1976 and 8.6 m in 1977 (Table 3). The difference between nest heights for 1976 and 1977 was significant ($t = 1.86$, P 0.05, d.f. = 34) (Steel and Torrie 1960).

Twelve of 17 nests used in 1977 were located within 1 km of a nest active in 1976 and four of the 12 were the identical site.

Table 2. Geologic structures used for nesting by ferruginous hawks in Harding County.

	Number of nests			
	1976	1977	Total	Percent
River bed mounds	1	0	1	2.6
River cutbank	2	6	8	21.0
Low hill	4	1	5	13.1
Mud butte	12	9	21	55.3
High vegetated hill	0	3	3	7.9

Table 3. Height (m) of geologic structures used by ferruginous hawks as nest sites.

Nest Height	1976	1977	Total	Percent
Level ground	2	1	3	8.3
0-3	4	0	4	11.1
3-6	3	5	8	22.2
6-9	4	3	7	19.5
9-12	5	3	8	22.2
12-15	1	4	5	13.9
Greater than 15	0	1	1	2.8
Mean	6.1	8.7	7.3	

Smith and Murphy (1973) reported that ferruginous hawks reoccupied the same nest site for as many as four consecutive years. Nest size averaged 31 cm high, 121 cm across, and 58 cm in nest cup diameter.

Nest materials were primarily standing dead vegetation. The outer basal portion of the nest was constructed mainly with sagebrush branches up to 2.5 cm in diameter. Barbed and baling wire, twine, paper, plastic, and dried cow manure were quite frequently added to the nest. The nest cup was usually lined with buffalo grass (Buchloe dactyloides) and a few pieces of paper and dried manure.

In areas where trees are relatively common ferruginous hawks often place their nests 2 to 4 m above the ground in an isolated tree. Cottonwoods (Populus spp.) and especially junipers (Juniperus spp.) are the trees most frequently used for nesting (Platt 1971, Howard and Powers 1973, Smith and Murphy 1973). In treeless areas or badlands ferruginous hawks nest on low cliffs, buttes, cutbanks, or hills (Ward 1968, Weston and Ellis 1968, Snow 1974).

Although several riparian areas and ravines within the study area supported tree growth, no active ferruginous hawk nests were found in trees. Craighead and Craighead (1956) noted that great horned owls (Bubo virginianus) tended to dominate a nesting population of raptors. It is the earliest nesting raptor, causes nest desertion by its presence, and actively preys on other raptors. Great horned

owls were common on the study area and their nesting was under way when the ferruginous hawks returned in the spring.

Early in the nesting season ferruginous hawks are very intolerant of their own as well as of other species of raptors (Olendorff 1971). This intolerance prevented their nesting in close proximity to great horned owls. The intolerance combined with a high population of great horned owls prevented the hawks from nesting in trees, forcing them to construct their nests on cutbanks, hills, and buttes. Olendorff (1972) observed a displacement of ferruginous hawks by great horned owls from more to less favorable nesting sites.

Other researchers have reported that the incidence of ground nesting by ferruginous hawks ranged from 3 percent (Howard 1975) to 52 percent (Weston 1969). In the present study all nests were located on the ground, constructed on a cutbank, hill, or butte. Either the earlier nesting great horned owls were effective in displacing ferruginous hawks from tree nest sites or the hawks were simply selecting ground sites in preference to tree nests. Active selection of ground nesting sites might be influenced by preference for exposed rather than shady nest sites, easy access to the nest from all sides, lack of visual obstructions which would be present in a tree nest, or ground nest locations which would be more remote from other nesting raptors than nests located in trees.

Of the nest sites observed in this study several factors may have influenced nest site selection. All sites enabled birds to view a large area surrounding the nest. Situating the nest at a good vantage point would allow adults to detect both potential predators and prey from the nest. It was extremely difficult to climb most nest structures, this could deter some predators and give the hawks an advantage in driving others away.

The aspect or direction of nest exposure appears to be nvolved in nest site selection. Aspect selection could be controlled y selection for exposure to the sun, shade, and, or the prevailing inds. In northern Utah, where the prevailing early summer winds re from the south or southeast, Weston (1969) found that 55 percent f the ground nests had east exposures and 23 percent had south xposures. Lokemoen and Duebbert (1976) found all ground nests riented to the west in northcentral South Dakota where prevailing vril winds are primarily northwesterly (U.S.D.I. 1970). In the esent study 91.4 percent of all nests were oriented to the west south or were located on top of the nest structure (Table 4). evailing winds in northwestern South Dakota blow from the south d southwest in late spring and summer (Spuhler et al. 1971). acement of nests with access to a prevailing wind would allow ending adults to become airborne without difficulty. Nestlings ring the age of fledging were often observed facing into the d with their wings spread. Exposure to high winds before leaving

Table 4. Direction of exposure of active ferruginous hawk nests in Harding County during 1976 and 1977.

	North	South	East	West	Top
1976	0	4	1	5	8
1977	1	5	2	3	6
Total	1	9	3	8	14

the nest may accustom fledglings to conditions similar to those encountered during flight and thereby enable them to attain some of the coordination necessary for flight.

McGahan (1968) concluded that the direction of the rays of the sun influenced nest site selection in golden eagles. He thought that exposure to the sun was especially important during the early spring months because air temperatures were frequently below freezing. The warming effect of the sun would be advantageous to both the incubating adults and the eggs. In Harding County air temperatures below freezing occurred frequently early in the incubation period. It would be to the advantage of incubating ferruginous hawks to place their nests in locations where they could be warmed by the sun.

Only four of 35 ferruginous hawk nests provided any shade at all and of the four only two provided a substantial amount of shade during the hottest part of the day. Olendorff (1973) concluded that direct sunlight was detrimental to overall nesting success of ferruginous hawks after observing lower productivity in unshaded than in shaded nests. Kochert (1972) attributed the deaths of eight 4 to 8 week old eaglets to heat prostration after a prolonged hot period. All the eaglets were from nests with southern or western exposures which received direct sunlight during the afternoon. Nestling ferruginous hawks have relatively large gapes and a considerable amount of heat is lost during their almost constant

gullar fluttering. No deaths were attributed to heat prostration even though adults discontinued shading the young 10 to 12 days after hatching. Direct exposure of nests to the sun is not a detrimental factor for ferruginous hawks and may in fact be beneficial, providing added warmth for incubating birds in early spring and thereby reducing energy demands.

esting Density

In 1976, 24 pairs of ferruginous hawks were observed in the udy area, 17 pairs and two unpaired adults were present in 1977. erage distance between active nests was 7.2 and 6.4 km during e two nesting seasons (Table 5). Crude densities on the 7000 km^2 idy area were 292 km^2 per pair in 1976 and 412 km^2 per pair in 7. In 1976, when 18 of 24 pairs attempted to nest crude density 389 km^2 per nest attempt. All pairs observed in 1977 attempted nest. Ecological density of nesting ferruginous hawks was km^2 per nest attempt in 1976 and 99 km^2 per 1977 nest attempt. During the 1976 breeding season six pairs occupying territories arly April did not attempt to nest. There was apparently a cient quantity of unoccupied nest sites and an adequate prey available. Ferruginous hawks do not breed until their third urth year (Brown and Amadon 1968). Perhaps some adults were l with sexually immature birds incapable of completing the ng cycle. Three paired individuals which had not yet attained

Table 5. Linear distance (km) between active nests during 1976 and 1977.

	N	Nearest	Furthest	Mean	S.D.
1976	18	2.4	15.0	7.2	3.59
1977	17	2.0	14.5	6.8	4.35

plummage characteristic of adults were observed. I found no information in the literature which correlated attainment of adult plummage and the age of sexual maturity in this species. It is likely that the paired birds in immature plummage were sexually immature and this prevented nesting.

The density of ferruginous hawks observed on this study area was much less than that found by other investigators but may be a more useful figure since this study area was not selected for its high population of ferruginous hawks as were several others. Lokemoen and Duebbert (1976) reported one pair of ferruginous hawks per 17.4 km^2 and Weston (1969) found one pair per 39.9 km^2 in Utah. Weston observed one pair for each 18.1 km^2 on a small area within his 1969 study area; this site was chosen because of its high densities of ferruginous hawks. Platt (1971) reported a density of 116 km^2 per pair in a Utah desert and Olendorff (1973) found 99.9 km^2 per pair on a 2,598 km^2 study area in Colorado.

Nesting Success

Thirteen of 18 nesting attempts by 24 pairs were successful in 1976 and 14 of 17 attempts of 17 pairs were successful in 1977. Nesting success, based on the total number of pairs present, was 54.2 percent in 1976 and 77.7 percent in 1977 (including the two unpaired birds as a pair). One of five nest failures in 1976 occurred approximately 25 days into the incubation period after

the adults abandoned the nest. Mammalian predators, the coyote (Canis latrans) and the red fox (Vulpes vulpes), were responsible for three of five nest failures in 1976 and one of three failures in 1977. One 1976 brood was deserted and died of exposure, starvation or a combination of these factors. The young of two 1977 broods probably died of exposure after 10 days of severe thunderstorms and high winds which occurred in mid-June. Clutch size, production, nest success, and other breeding data are summarized in Tables 6 through 9.

Infertility was the most common cause of egg loss accounting for eight of 14 unhatched eggs. Three fertile eggs failed to hatch, three young died after being abandoned by the adults, and predation was a factor in 12 nestling deaths in 1976 and five in 1977. The youngest bird in each of two broods disappeared at the age of about 14 days. Both of these birds weighed considerably less than their nest mates, although they were only a few days younger. Their weights fluctuated widely while their nest mates gained weight constantly. Weight fluctuations observed during a period when growth is normally logarithmic (Olendorff 1973) indicated that these youngest birds were not receiving a sufficient quantity of food. Neither bird was found in or around the nest and I believe that they were either killed and eaten by the larger nestlings or died and were then consumed. Ingram (1959) reported that fratracide occurred frequently among raptors.

Table 6. Frequency distribution of clutch size of ferruginous hawks in Harding County.

		Clutch size						
	N	1	2	3	4	5	Mean	S.D.
1976	18	0	16.7	38.9	44.4	0	3.44	1.8
1977	17	0	23.5	29.4	41.2	5.9	3.29	1.7
Total	35	0	20.0	34.3	42.9	2.8	3.37	1.7

Table 7. Production of ferruginous hawks per nest attempt and successful nest.

		Young hatched per		Young fledged per	
	N	Attempted	Successful	Attempted	Successful
1976	18	2.89	4.00	1.89	2.61
1977	17	3.06	3.71	2.29	2.78
Total	35	2.97	3.85	2.08	2.70

Table 8. Survival of nestling ferruginous hawks in Harding County during 1976 and 1977 (percent in parentheses)

	Eggs	Hatch	Fledge	Starve	Predation	Deserted	Other
1976	59	52(88)	34(58)	3(5)	12(20)	3(5)	0
1977	56	52(93)	39(70)	0	5(9)	0	8(14)
Total	115	104(90)	73(64)	3(3)	17(15)	3(3)	8(7)

Table 9. Nesting success of ferruginous hawks in Harding County.

	Total pairs	Nesting attempts	Successful nests	Young hatched	Young fledged	Nesting success[1]
1976	24	18	13	52	34	54.2%
1977	17	17	14	52	39	82.3%
Total	41	35	27	102	73	65.9%

[1]Nesting success based on the number of pairs present and the number of successful nests.

All nests destroyed by predators during 1976 and 1977 were located on hills or mud buttes less than 5 m high. These structures could have easily been climbed, thus rendering them insecure as nest sites. Fresh fox scats were found at three of four destroyed nests, implicating the red fox as the responsible predator.

No renesting attempts were made during the study. When a pair abandoned its nest or a nest was destroyed by predators or adverse weather conditions the adults usually remained in the vicinity of the nest for the duration of the nesting season. Defense of the nest decreased considerably after nest failure and ceased completely after a few weeks. When an intruder approached an unsuccessful nest the adults simply soared high overhead, occasionally emitting short calls. Others have reported similar behavior and lack of renesting by this species (Davy 1930, Olendorff 1973, Howard and Powers 1973, Smith and Murphy 1973, Howard 1975).

Behavior

Woffinden (1975) stated that when an intruder is present both adults soared high overhead uttering shrill calls, with occasionally one or both making a perfunctory swoop at the intruder. Similar soaring behavior was observed during this study but swooping at the researcher was frequent. Males were most active in nest defense. Males and occasionally females swooped from two to ten times while I was at the nest, often approaching within 1 m.

After five to seven visits to a particular nest, defensive behavior usually subsided to a point where the adults soared and called for a few minutes and then perched nearby awaiting my departure. Both adults, especially the male, usually escorted me to one-half km away from the nest, soaring but not calling.

On one occasion as I approached the nest the resident female circled and called for a few minutes and then left the area. She returned and after circling a few times swooped toward me, dropping 7 to 10 cm diameter stone from her feet as she pulled up from her dive. The stone landed approximately 5 m from me, this behavior was not repeated. Janes (1976) reported the apparent use of rocks nest defense by a raven (Corvis corax).

Weston (1969) and Woffinden (1975) reported the presence of third bird joining a pair of ferruginous hawks involved in nest fense. I observed this type of behavior on two occasions; each ra bird was an adult ferruginous hawk but sex could not be ermined.

I observed nesting birds defending their territories against er raptors on four occasions, each time the male was the defender. e a pair of ferruginous hawks flew over an occupied nest and resident male flew up and escorted them away from the nesting t. More aggressive behavior was directed toward intruding len eagles (Aquila chrysaetos). On several occasions I observed uginous hawks swooping repeatedly at intruding eagles. Eagles

reacted by turning their heads toward the diving hawk or by turning over on their backs and extending their legs and talons toward the hawk, occasionally making contact. This interaction continued until the eagles were well away from the nest. Weston (1969) observed little aggressive behavior directed toward golden eagles although he reported ferruginous hawks attacking but not making contact with ravens. In this study a ferruginous hawk was observed attacking and driving off a marsh hawk (Circus cyaneus) which had entered an area in which the ferruginous hawk was hunting.

Dawson (1909) labeled ferruginous hawks "cowards" because of their generally passive nest defense and Taverner (1943) questioned how these ground nesters escaped predation by coyotes. Angell (1969) described in detail the defensive reaction of a pair of ferruginous hawks to the presence of a coyote near their nest. They were extremely aggressive in driving the coyote away from the nest, striking it several times and often diving as a pair with one bird distracting the coyotes attention and the other striking it. In this study there was no noticeable difference in agressive behavior between birds nesting in secure situations and birds nesting in insecure situations.

Sexing Criteria

Mean flexed hallux diameters were 17.8 mm for females and 14.4 mm for males (Table 10). Hallux measurements of females

Table 10. Hallux diameters (mm) of unfledged ferruginous hawks more than 30 days old.

Males		Females	
13.7	15.0	16.7	17.2
15.2	14.2	17.0	16.0
13.6	14.1	17.0	17.6
12.6	13.8	17.9	15.6
13.2	14.5	15.8	18.0
15.2	12.8	17.5	17.8
13.6	13.8	16.9	18.5
12.7	12.8	18.5	18.4
14.4	13.6	17.2	18.2
14.0	14.8	19.4	18.5
14.9	15.0	19.2	19.2
15.7	14.8	18.8	18.7
14.7	15.0	19.3	17.7
15.8	14.8	18.5	
15.5	15.4		
15.8	14.6		
N = 32		N = 27	
Mean = 14.36		Mean = 17.82	
S.D. = 0.93		S.D. = 1.06	

averaged 1.24 times as large as those of males. A comparison of the means using Student's t test showed a highly significant difference (t = 13.07, P 0.0001, d.f. = 56). Mean body weights were 1577 g for females and 1114 g for males (Table 11), females veraged 1.42 times as large as males. Body weights of males and emales were significantly different (t = 19.2, P 0.0001, d.f. = 56). ny unfledged ferruginous hawk more than 30 days old with a flexed allux diameter greater than 15.5 mm and weighing more than 1300 g s a female. Approximately 95 percent of the nestlings fell clearly to either the male or the female category, the remaining 5 percent re borderline in one measurement but clearly distinguishable, garding sex, in the other measurement. Weights were slightly gher than those recorded by either Olendorff (1971) or Howard 975).

mmage Types

Brown and Amadon (1968) list four distinct plummages for ruginous hawks: light, dark, red, and immature. Immature birds occur in both light and dark phases. Three distinct plummages observed on the study area. Of 84 adults two (2.4 percent) dark phase and 82 (97.6 percent) were light phase. All fledglings light phase immature plummage. Olendorff (1973) found that phase birds accounted for 3 percent of the adult population rruginous hawks in Colorado and Howard (1975) observed 3.5 nt dark phase adults in Utah and Idaho.

Table 11. Weight (g) of unfledged ferruginous hawks more than 30 days old.

Males		Females	
1005	1117	1508	1308
1034	1120	1357	1442
1088	1092	1670	1555
1078	1152	1340	1565
1012	1000	1565	1650
1115	1110	1775	1640
1102	1040	1605	1500
1210	1205	1435	1535
1165	1030	1660	1630
1160	1150	1640	1610
1075	1100	1795	1650
1175	1095	1635	1725
1140	1230	1530	1660
1180	1270	1620	
1060	1080		
1145			
N = 31		N = 27	
Mean = 1114		Mean = 1578	
S.D. = 67.2		S.D. = 122.5	

Diet During the Breeding Season

During 1976, 342 pellets and individual remains of prey animals were collected; 348 items were collected in 1977. Mammals represented 70.3 percent of the total prey items while birds and reptiles accounted for 27 and 2.6 percent respectively (Table 12). Thirteen-lined ground squirrels, western meadowlarks (Sturnella neglecta), and white-tailed jackrabbits were the most frequently occurring prey items. Eighty-two percent of all western meadowlarks identified from pellets and prey remains were juveniles. These findings supported the results of Cameron (1914), Angell (1969), and Howard (1975) that birds taken as prey were primarily recent fledglings.

In the west, black-tailed jackrabbits (Lepus californicus) were an important food item of ferruginous hawks (Weston 1969, Smith and Murphy 1973, Howard 1975). The importance of ground squirrels as prey for ferruginous hawks has been observed in Colorado (Olendorff 1973), Utah (Howard 1975), and South Dakota (Lokemoen and Duebbert 1976). May (1935) and Bent (1937) found that mammals are the most common prey item.

Mammals accounted for 94.1 percent of prey biomass, birds 4.9 percent, and reptiles and amphibians 1.0 percent (Fig. 2). White-tailed jackrabbits were the single most important prey item, composing 68.4 percent of total biomass. Thirteen-lined ground squirrels accounted for 15.0 percent and eastern cottontails (Sylvilagus virginianus) 5.3 percent of total biomass. Western

Table 12. Analysis of pellets and prey remains found at ferruginous hawk nests in 1976 and 1977, number of occurrences and percent frequency of occurrence.

	1976		1977		Total	
	No.	%	No.	%	No.	%
Mammals						
Thirteen-lined ground squirrel (Citellus tridecemlineatus)	156	45.6	147	42.5	303	43.9
White-tailed jackrabbit (Lepus townsendi)	18	5.3	49	14.2	67	9.7
Northern pocket gopher (Thomomys talpoides)	21	6.2	33	9.5	54	7.8
Eastern cottontail (Sylvilagus floridanus)	4	1.2	9	2.6	13	1.9
Blacktail prairie dog (Cynomys ludovicianus)	1	0.3	6	1.7	7	1.0
Longtail weasel (Mustela frenata)	0	0	3	0.9	3	0.4
Deer mouse (Peromyscus maniculatus)	1	0.3	1	0.3	2	0.2
Ord kangaroo rat (Depodomys ordi)	1	0.3	0	0	1	0.1
House mouse (Mus musculus)	2	0.6	0	0	2	0.3
Western harvest mouse (Reithrodontomys megalotis)	2	0.6	0	0	2	0.3
(Peromyscus spp.)	3	0.9	0	0	3	0.4
Hispid pocket mouse (Perognathus hispidus)	16	4.7	5	1.4	21	3.0
Total	229	67.0	256	74.0	485	70.4
Birds						
Western meadowlark (Sturnella neglecta)	91	26.6	71	20.5	162	23.5
Horned lark (Eremophila alpestris)	6	1.7	3	0.9	9	1.3
Chestnut collared longspur (Calcarius ornatus)	1	0.3	0	0	1	0.1
Gray partridge (Perdix perdix)	1	0.3	0	0	1	0.1
Common flicker (Colaptes auratus)	0	0	4	1.1	4	0.6
Sprague's pipit (Anthus spragueii)	0	0	3	0.9	3	0.4
Lark bunting (Calamospiza melanocorys)	2	0.6	2	0.6	4	0.6
Sparrow unknown	3	0.9	0	0	3	0.4
Total	104	30.4	83	24.0	187	27.0

Table 12. Continued

	1976		1977		Total	
	No.	%	No.	%	No.	%
Reptiles						
Western hognose snake (*Heterodon nasicus*)	6	1.7	6	1.7	12	1.7
Gopher snake (*Pituophis melanoleucus*)	2	0.6	2	0.6	4	0.6
Short-horned lizard (*Phrynosoma douglassi*)	1	0.3	0	0	1	0.1
Leopard frog (*Rana pipiens*)	0	0	1	0.3	1	0.1
Total	9	2.6	9	2.6	18	2.6
TOTAL PREY ITEMS	342	100.0	348	100.0	690	100.0

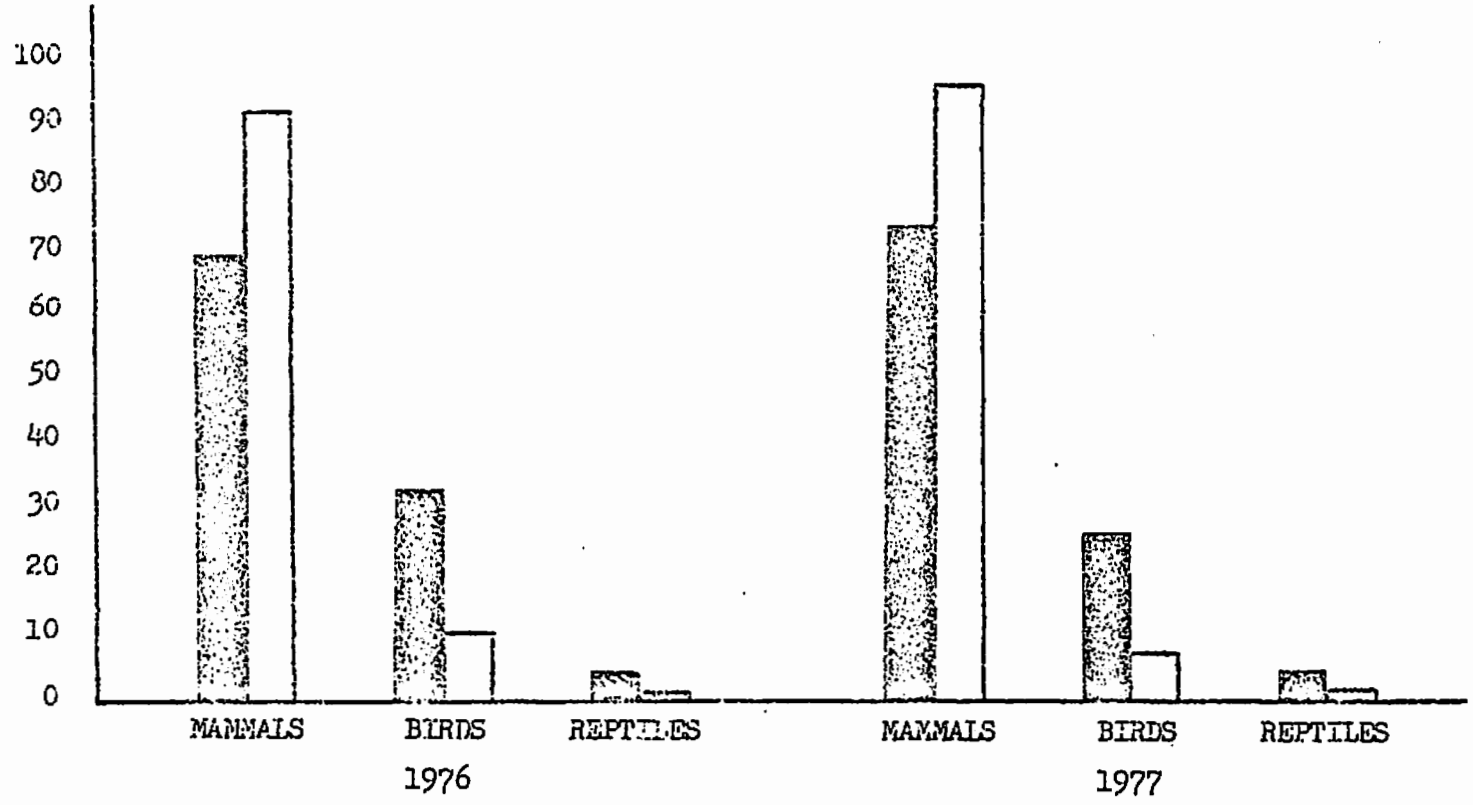


Fig. 2. Percent frequency of occurrence and percent biomass of mammals, birds, and reptiles identified in pellets and prey remains collected at ferruginous hawk nests.

meadowlarks, although only second to ground squirrels in frequency, accounted for only 3.7 percent of the total biomass (Fig. 3).

Juvenile Post Fledging Activity

Areas utilized by fledglings were determined from 2147 locations obtained from six radio-tagged birds. Young birds were closely associated with the nest for one to two weeks after fledging. With one exception no juvenile birds were located at the nest later than 14 days after fledging. Thus dependence of the fledged young on the nest site as a place to obtain food was limited to two weeks after fledging. By this time the young had apparently developed the flying and hunting coordination necessary to make them independent of the nest. They no longer required the security offered by the nest and were able to accompany their parents away from it. For the first two weeks after fledging the young returned to their nests to obtain food from the adults and to roost but this activity also stopped after two weeks.

With two exceptions utilized areas expanded with each week after fledging (Table 13). Two weeks after fledging birds 15 and 16, a male and female from the same nest, shifted their utilized area from the nest area to a large hill (Figures 4 and 5). They were often observed perching on or flying in the vicinity of this hill. Birds 11 and 13 also expanded their range during the second week off the nest to include several buttes which provided them with perching sites (Figures 6 and 7). This area corresponded to

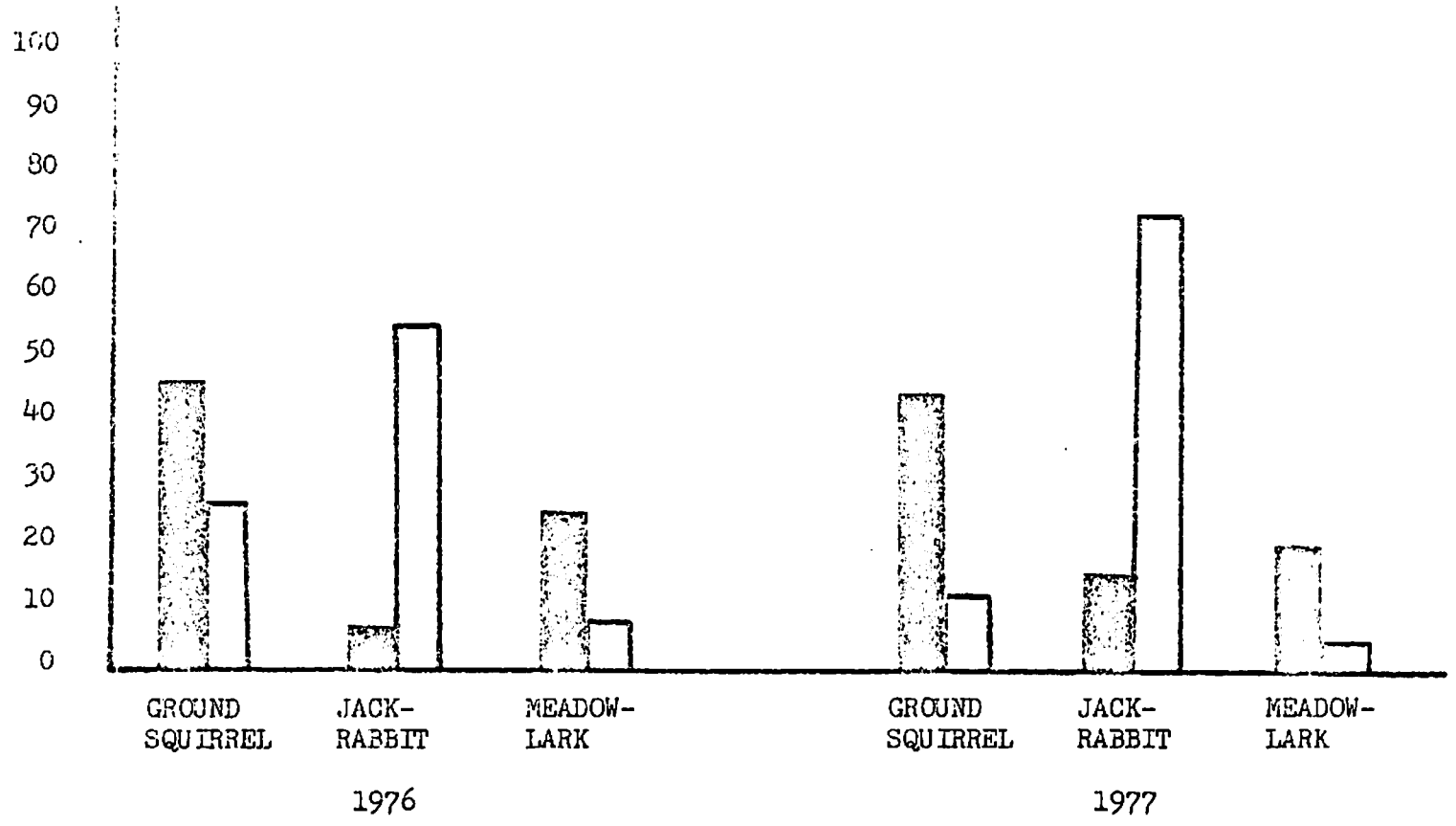


Fig. 3. Percent frequency of occurrence and percent biomass of thirteen lined ground squirrels, white tailed jackrabbits, and western meadowlarks identified from pellets and prey remains collected at ferruginous hawk nests.

Frequency of occurrence ▒ Biomass □

Table 13. Area (ha) utilized by radio-tagged juvenile ferruginous hawks after fledging.

Bird No.	Sex	Weeks after fledging			
		1	2	3	4
09	M	81.9	365.2	772.8	776.6
10	F	128.2	315.9	454.0	657.7
11	F	20.4	70.6	247.2	502.5
13	F	28.9	210.7	376.6	793.7
15	F	88.3	9.0	19.3	94.1
16	F	13.2	7.8	15.6	105.2

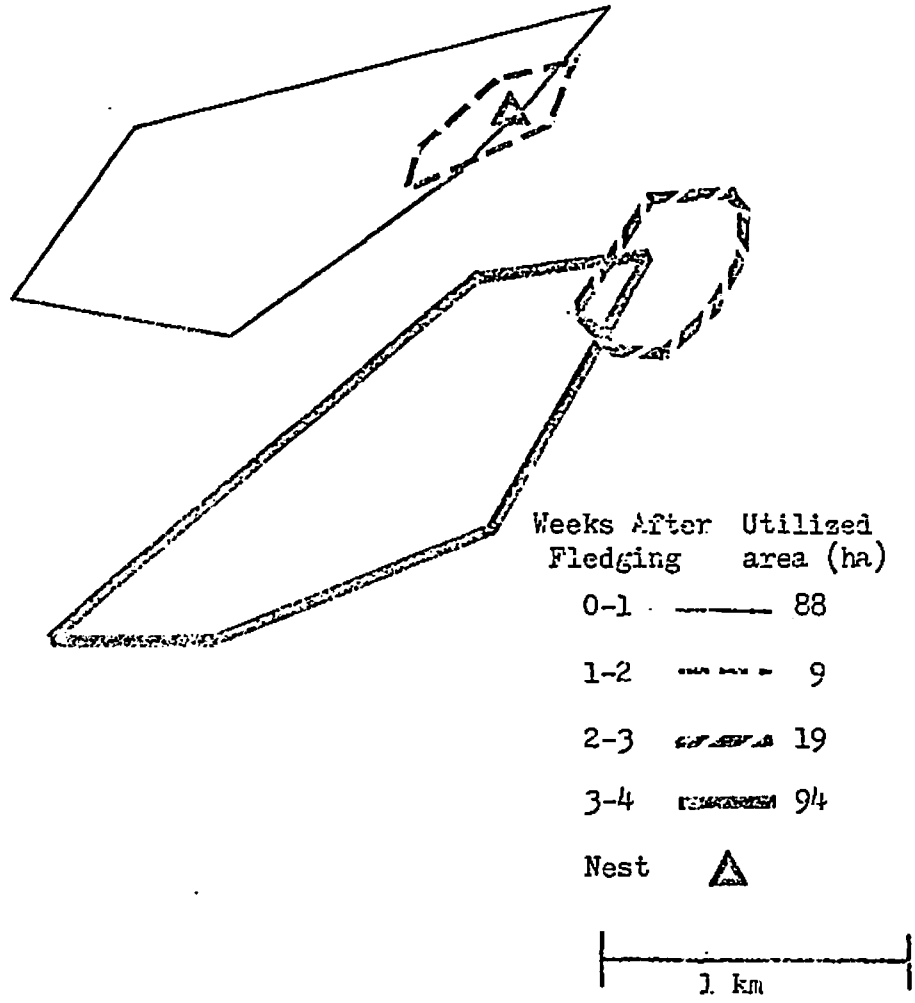
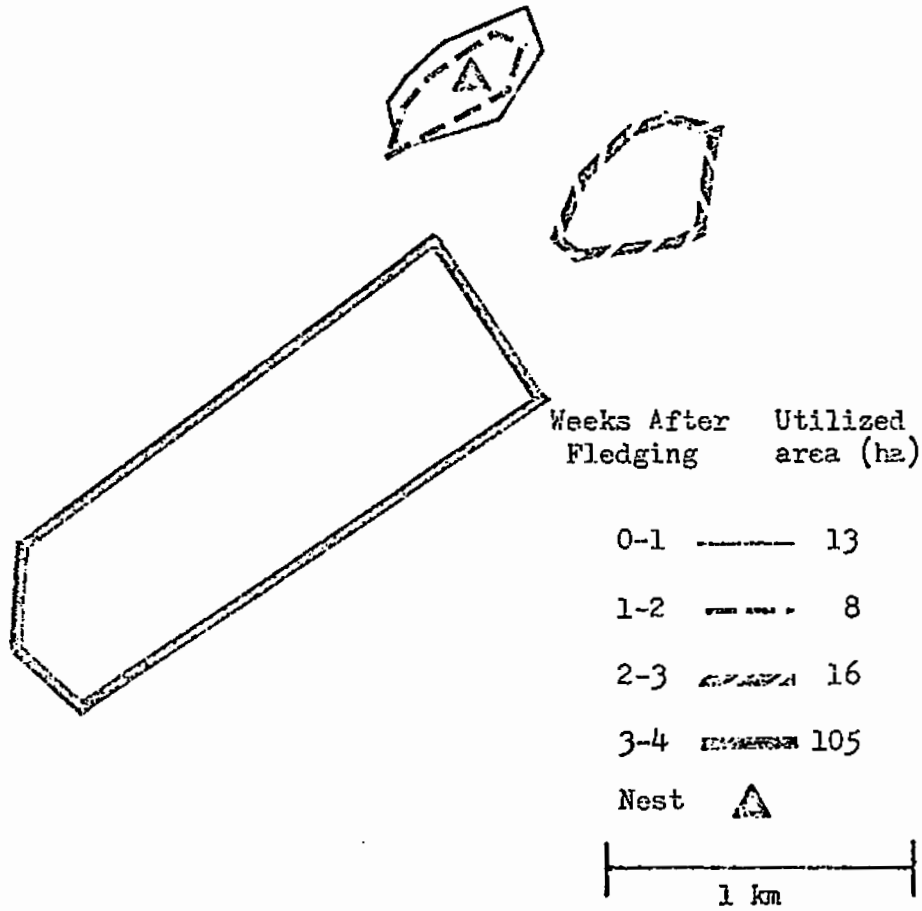


Fig. 4. Area utilized by radio-tagged ferruginous hawk 15 (female) plotted on a weekly basis.



.g. 5. Area utilized by radio-tagged ferruginous hawk 16 (female) plotted on a weekly basis.

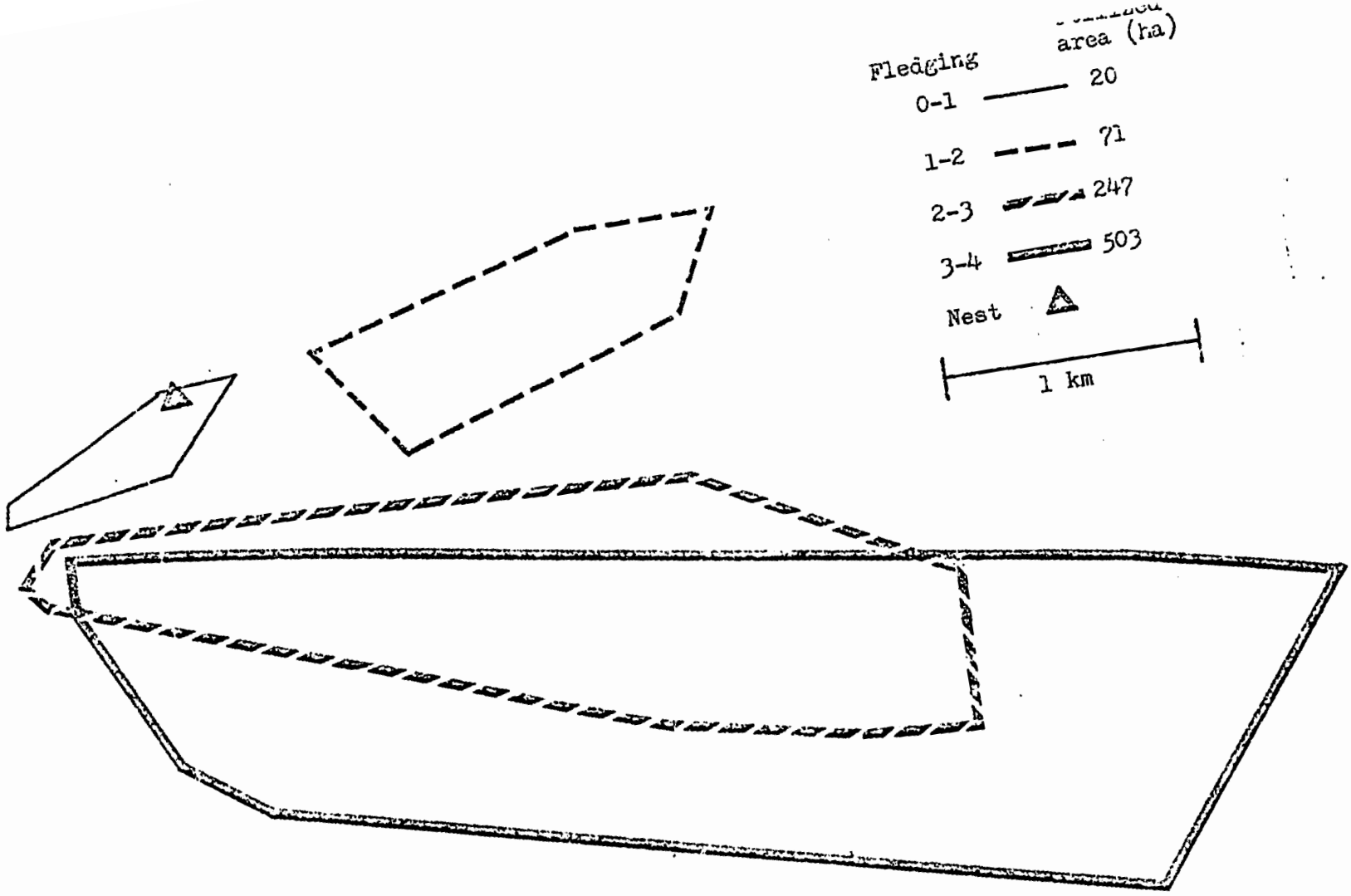


Fig. 6. Area utilized by radio-tagged ferruginous hawk 11 (female) plotted on a weekly basis.

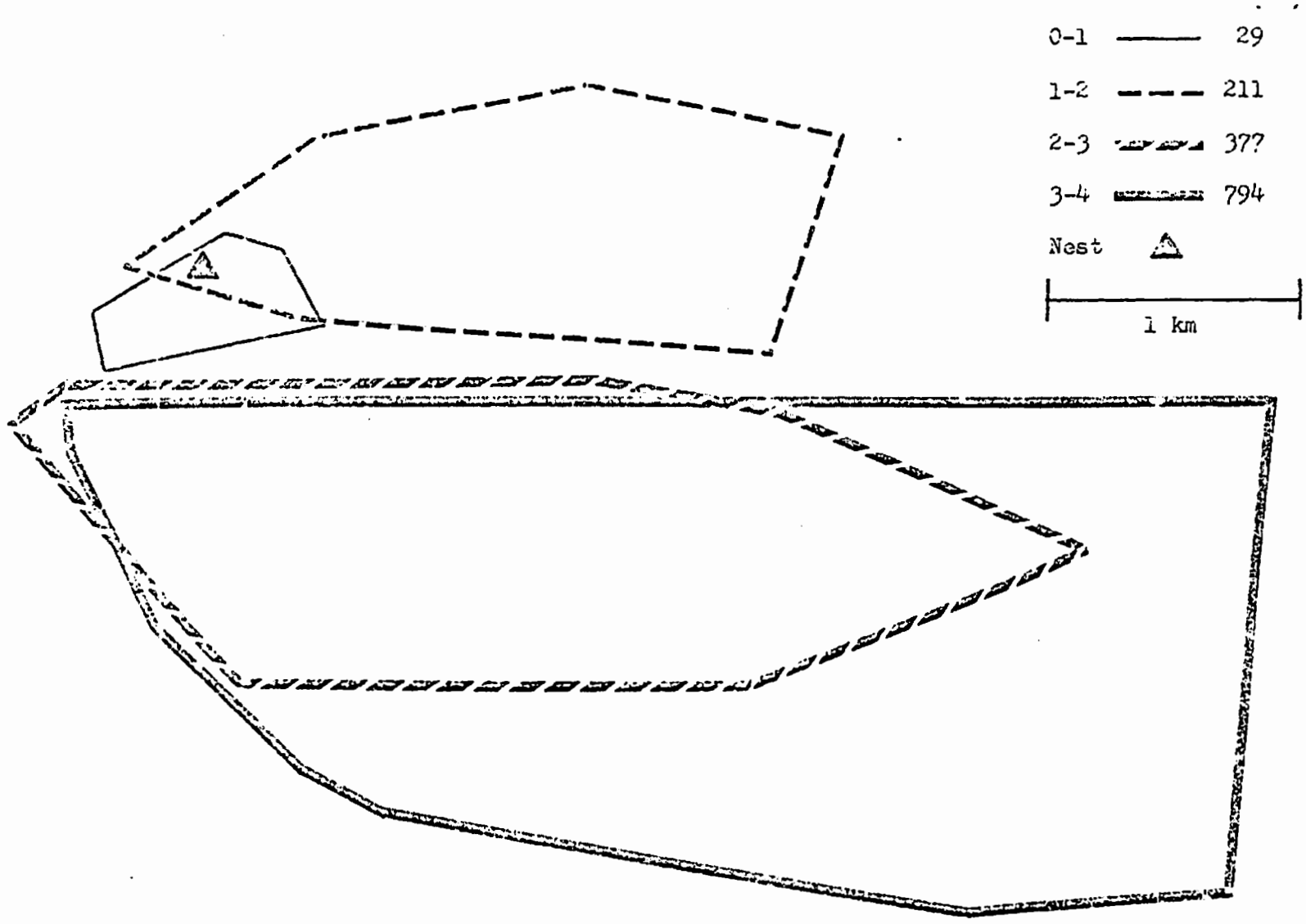


Fig. 7. Area utilized by radio-tagged ferruginous hawk 13 (female) plotted on a weekly basis.

the range utilized by their parents for hunting. During their third and fourth weeks off the nest the activity of birds 11 and 13 shifted to an area from which wild hay had recently been cut. The one-half ton round bales probably provided numerous hunting perches and the short grass made potential prey readily visible.

Birds 9 and 10 expanded their utilized area weekly (Figures 8 and 9). The general direction of range expansion corresponded with the area of least human activity in the vicinity of their nest. A heavily used highway to the east and ranch buildings to the north and west may have restricted the expansion of their activity in these directions.

At the beginning of the fifth week after fledging the radio signals of birds 9 and 10 could not be located. Visual observation of the area the birds had been using revealed no sign of either the juveniles or the adults. Similar loss of radio signals and the disappearance of both young and adults occurred for the other four radio-tagged birds during the middle of the fifth week after fledging. Other occupied nest areas were also deserted during this period and I feel that many ferruginous hawks were leaving the study area during the first week in September. Approximately five and one-half months elapsed from the arrival of the adults in late March until their departure in early September.

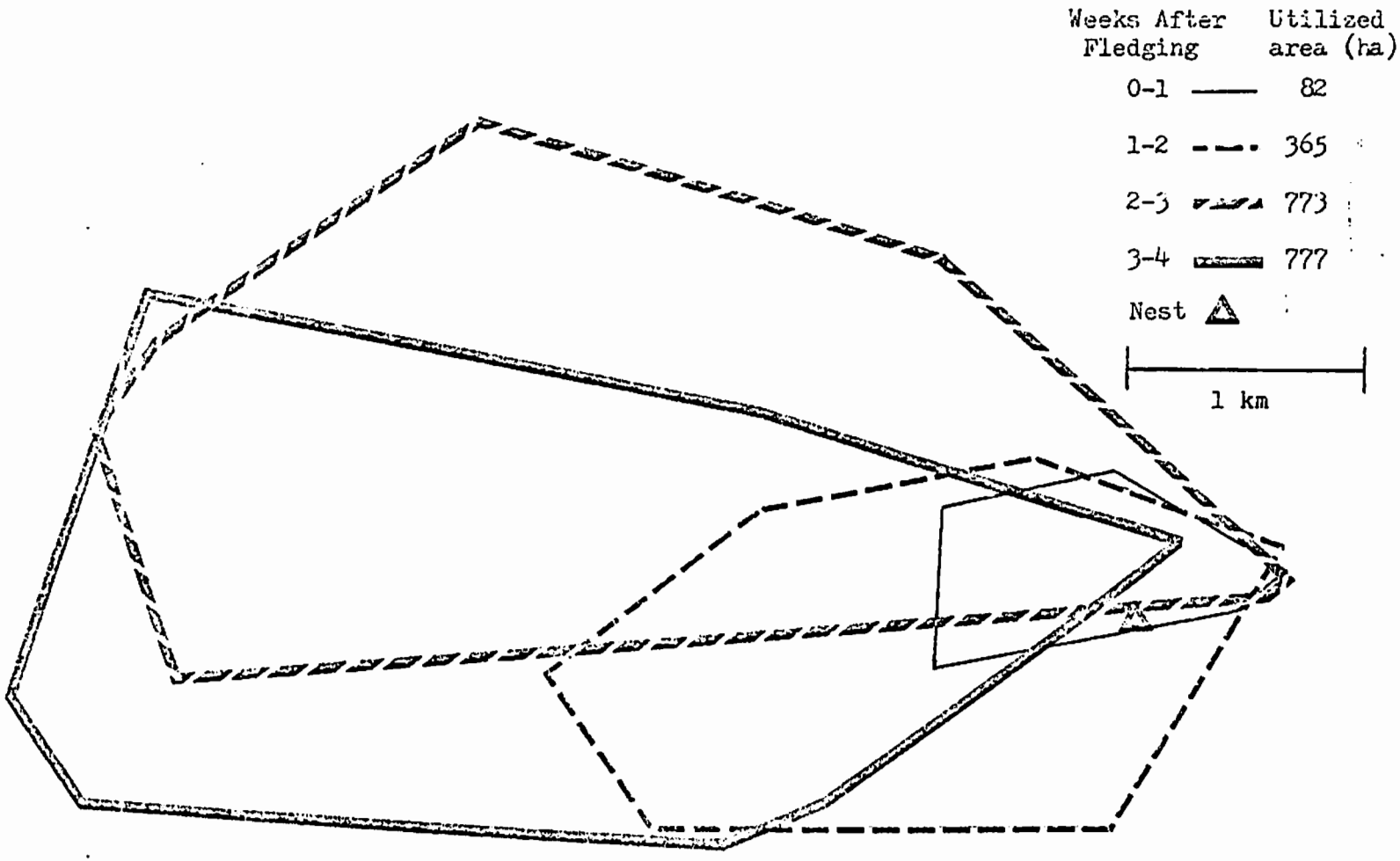


Fig. 8. Area utilized by radio-tagged ferruginous hawk 09 (male) plotted on a weekly basis.

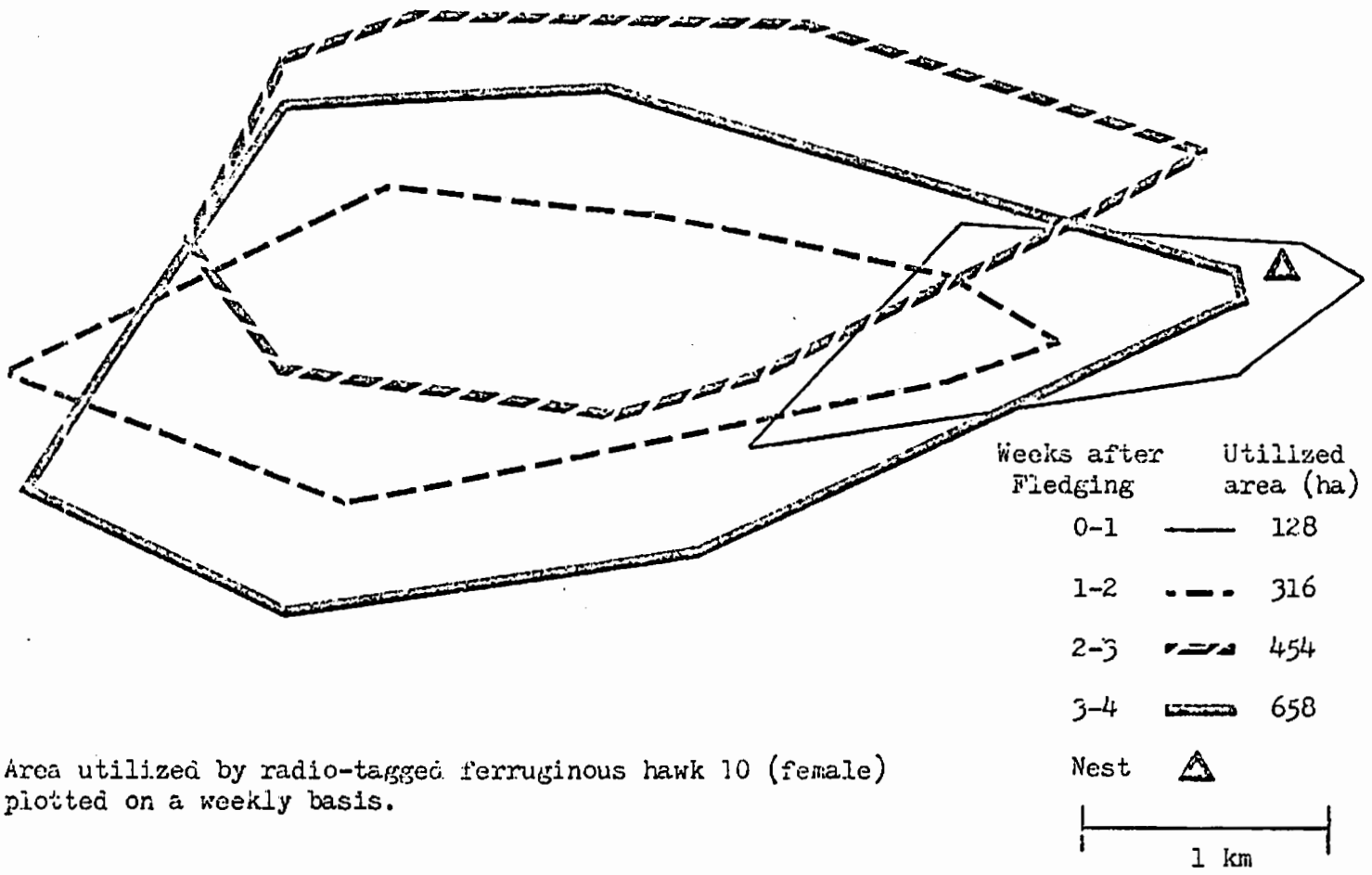


Fig. 9. Area utilized by radio-tagged ferruginous hawk 10 (female) plotted on a weekly basis.

Impact of Human Activity and Development

Ferruginous hawks are sensitive to human activity and will readily abandon their nests, even after a single visit, if the young are still unhatched (Snow 1974). Activities such as plowing and discing, mineral exploration and extraction, or off-road recreational vehicle use can result in nest abandonment when conducted in the vicinity of a nest. Such activities occurring repeatedly after the young have hatched may keep the attending adults off the nests for excessive periods of time.

Olendorff (1973) observed a larger clutch size and a 24.5 percent greater probability of fledging from remote nests than from nests that were easily accessible to the public. In Harding County only one nest was in an area easily accessible to the public, making a comparison between remote and accessible nests impractical. I measured the distance from 36 active nests and from 36 randomly selected points to the nearest location of regular human activity. The mean distance from active nests to the nearest human activity was 3.31 km while the mean distance from random points was 2.47 km. The difference between the means was significant ($t = 2.33$, $P < 0.01$, d.f. = 70). Lokemoen and Duebbert (1976) observed that 11 of 12 ground nests of ferruginous hawks in northcentral South Dakota were located farther from human activity than the mean distance of randomly selected points.

Slight differences in clutch size and hatchability were observed between the two nesting situations. Fifteen of 18 nests (83.3 percent) located farther from human activity than the mean of randomly selected points were successful, while only 12 of 17 nests (70.1 percent) located closer to human activity than the random point mean were successful. The probability of fledging from a more distant nest was 11.4 percent greater than from a nest closer to occupied dwellings.

Dry farming for alfalfa and small grains is increasing in Harding County. Between 1970 and 1974, 7695 ha of uncropped grassland was converted to cropland. During fiscal year 1975 this first time conversion to cropland figure was 711.6 ha while 4752.3 ha of grassland were converted to cropland during fiscal year 1976 (Loy Allen, pers. comm. Sixth District Council of Local Governments, P.O. Box 1586, Rapid City, South Dakota 57709). This trend toward more intensive agriculture is expected to continue.

The implications of increased conversion of pasture to cropland are important to the ferruginous hawk population of Harding County. Monotypic fields of small grain would probably support a lower prey base for ferruginous hawks than would native grassland. Where farming occurs in a traditional nesting area the result will be a shift in the hunting range to a location more distant from the nest or complete abandonment of the nesting area. Increased springtime farming activity could interfere with courtship or cause nest abandonment.

Harding County has extensive mineral resources including oil, gas, uranium, and coal. In 1975, there were 32 producing oil wells and 17 new wells were drilled after extensive exploration. A natural gas deposit has been identified and 14 companies are actively exploring for uranium. Mineral leases and coal and uranium prospecting permits have been issued on over 133,650 ha of state land. Extensive prospecting is also occurring on private land. Some coal development may occur in the eastern portion of the county as there are marginal quantities of uranium inbedded in the coal (Loy Allen, pers. comm.).

An environmental impact statement has been written safeguarding raptor nesting areas on U.S. Forest Service lands from excessive harrassment (U.S.D.A. 1976b) but no such plans exist for state or private lands. The extensive activity associated with mineral exploration and development in once remote areas of the county will certainly have a detrimental effect on ferruginous hawks.

The intensification of agriculture, mineral exploration and evelopment, and increased recreational demands of energy related orkers will reduce the number of areas of Harding County which re suitable for nesting ferruginous hawks. Since ferruginous awks require remote areas for nesting the increase in human activity ill probably result in a diminished breeding population of this ecies in Harding County.

CONCLUSION

The breeding population of ferruginous hawks in Harding County remained stable during the 2 years of study. However, the total seasonal resident population changed substantially. In 1976, 24 pairs were present with 18 attempting to nest while in 1977 only 17 pairs were present and all attempted to nest. The cause of this 29 percent reduction in the seasonal resident population is unknown.

Total production of young was similar between the 2 years while overall nesting success was higher in 1977 than in 1976. This was attributed to a lower incidence of nest destruction by mammalian predators. In 1977 nests were placed on geologic structures which were significantly higher than nest structures used during 1976. The decrease in mammalian predation was probably the result of the birds selection of higher, less accessible structures for nesting.

With one exception radio-tagged juvenile ferruginous hawks were not dependent on the nest site for more than 2 weeks after fledging. Young remained at least partially dependent on the adults for food for a minimum of 30 days after fledging.

The breeding population of ferruginous hawks in Harding County appears stable at the present time, although the extreme sensitivity of these birds during the nesting season will certainly cause local populations to decline as human activity in remote

areas increases. Exploration for energy resources and the development associated with their extraction along with intensified farming will reduce the number of areas in Harding County suitable for ferruginous hawks.

SUMMARY

A two year study of ferruginous hawks nesting in Harding County, South Dakota, was begun in 1976. Objectives of the study were (1) to determine the population level of the ferruginous hawk in northwestern South Dakota; (2) to determine the ecological density of nesting pairs; (3) to document the reproductive success (clutch size, hatching rate, and fledging rate); (4) to document the food consumption of both young and nesting adult ferruginous hawks; (5) to estimate the proportions of different types of habitat associated with each hunting territory; and (6) to determine the post fledging activity of juveniles.

Ferruginous hawks arrived on the study area in late March and began egg laying in mid-April. Young birds first left the nests in late June. The ecological density of nesting ferruginous hawks was 104 km^2 per nest attempt in 1976 and 99 km^2 per attempt in 1977. Twelve of 17 nests used in 1977 were located within 1 km of a nest active in 1976 and four of the 12 were the same nest.

Clutch size averaged 3.44 in 1976 and 3.29 in 1977, while 1.89 young fledged per nest attempt in 1976 and 2.29 fledged per attempt in 1977. Weight and flexed hallux measurements were used to sex nestlings. Unfledged birds more than 30 days old with a flexed hallux greater than 15.5 mm in diameter and weighing more than 1300 g were females.

Six hundred and ninety food items were identified from pellets and prey remains collected in or around nests during the two year study. Mammals accounted for 94 percent of prey biomass, birds 5 percent, and reptiles 1 percent. Based on biomass, white-tailed jackrabbits and thirteen-lined ground squirrels were the most important prey items.

All but one nest was located in unbroken, lightly grazed prairie and were placed on the ground, on hills, buttes, or river cutbanks. Nests were usually located farther from occupied dwellings than were randomly selected points and were oriented toward the south and west.

Radio transmitters were placed on six juvenile ferruginous hawks as they neared fledging. The radio-tagged birds expanded their utilized areas during each successive week after fledging. Most ferruginous hawks had left the study area by mid-September, approximately 24 weeks after their arrival.

LITERATURE CITED

Angell, T. 1969. A study of the ferruginous hawk: adult and brood behavior. The Living Bird 8:225-241.

Arbib, R. 1972. The blue list for 1973. Am. Birds 26(6):932-933.

Baker, C. L. 1952. Geology of Harding County. South Dakota State Geological Survey, Report of Investigations No. 68. Vermillion, S.D. 39 pp.

Bent, A. C. 1937. Life histories of North American birds of prey. Bull. U.S. Natl. Mus. Part 1, 167:284-293.

Biggs, A. 1965. Are the roughlegs (B. regalis) returning? Can. Audubon 27(3):78-79.

Brown, L. H. and D. Amadon. 1968. Eagles, hawks, and falcons of the world. McGraw-Hill, New York. 945 pp.

Burt, W. H. and R. P. Grossenheider. 1976. A field guide to the mammals. Houghton Mifflin. Boston. 289 pp.

Cameron, S. E. 1914. The ferruginous rough-leg in Montana. Auk 31(2):159-167.

Craighead, J. J. and F. Craighead. 1956. Hawks, owls, and wildlife. Stackpole, Harrisburg, Pa. 443 pp.

Davy, G. L. 1930. Nesting of the ferruginous roughleg hawk in northern North Dakota. Oologist 47:14-17.

Dawson, W. L. 1909. The birds of Washington. Occidental Publishing, Washington, D.C. 194 pp.

Dunstan, T. C. 1972. A harness for radio-tagging raptorial birds. Inland Bird Banding News 44(1):4-8.

Fitch, H. F., F. Swenson, and D. F. Tillotson. 1946. Behavior and food habits of the red-tailed hawk. Condor 48(2):205-237.

Glading, B., D. F. Tillotson, and D. Selleck. 1943. Raptor pellets as indicators of food habits. Calif. Fish Game 29(1):92-121.

Hall, E. R. and K. R. Kelson. 1959. The mammals of North America. Ronald Press. New York. Vols. I and II, 1080 pp.

Hammerstrom, F. 1970. Think with a good nose near a nest. Raptor Res. 4:79-80.

Howard, R. 1975. Breeding biology of the ferruginous hawk in northern Utah and southern Idaho. M.S. Thesis, Utah State Univ., Logan. 60 pp.

_____ and L. Powers. 1973. Hawk of the desert. Anim. Kingdom 76(3):24-27.

Ingram, C. 1959. The importance of juvenile cannibalism in breeding biology of certain birds of prey. Auk 76(2):218-226.

Jacot, E. C. 1934. An Arizona nest of the ferruginous roughleg. Condor 36(1):84-85.

Janes, S. W. 1976. The apparent use of rocks by a raven in nest defense. Condor 78(3):409.

Kochert, M. 1972. Population status and chemical contamination in golden eagles in southwestern Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 102 pp.

Lokemoen, J. T. and H. F. Duebbert. 1976. Ferruginous hawk nesting ecology and raptor populations in northern South Dakota. Condor 78(4):464-470.

Luttich, S., D. H. Rusch, E. C. Meslow, and L. B. Keith. 1970. Ecology of red-tailed hawk predation in Alberta. Ecology 51(2):190-203.

May, J. R. 1935. The hawks of North America. Moore Press, New York, for the National Association of Audubon Societies. 40 pp.

McGahan, J. 1968. Ecology of the golden eagle. Auk 85(1):1-12.

Odum, U. P. 1971. Fundamentals of ecology. W. P. Saunders, Philadelphia, Pa. 546 pp.

_____ and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72(2):128-137.

Olendorff, R. R. 1971. Morphological aspects of growth in three species of buteos. Ph.D. Diss. Colorado State Univ., Fort Collins. 460 pp.

_____. 1972. The large birds of prey of the Pawnee National Grassland: nesting habits and productivity, 1969-1971. U.S.I.B.P. Technical Report No. 151. Colorado State Univ., Fort Collins. 59 pp.

_____. 1973. The ecology of the nesting birds of prey of northeastern Colorado. U.S.I.B.P. Technical Report No. 211. Colorado State Univ., Fort Collins. 233 pp.

Platt, J. B. 1971. A survey of nesting hawks, eagles, falcons, and owls in Curlew Valley, Utah. Great Basin Nat. 31(2):51-65.

Ray, T. D. 1968. Napthalene crystals as a protection for nesting raptors. Hawk Chalk 7(1):52-54.

Rothrock, E. P. 1937. Structural conditions in Harding County, South Dakota. South Dakota State Geological Survey, Report of Investigations, No. 28. Vermillion, S.D. 30 pp.

Smith, D. and J. R. Murphy. 1973. Breeding ecology of raptors in the eastern Great Basin of Utah. Brigham Young Univ. Sci. Bull. Biol. Ser. 18(3). 76 pp.

Snow, C. 1974. Habitat management series for unique or endangered species. Report No. 13. Ferruginous hawk. Bureau of Land Management. 23 pp.

Spuhler, W., W. F. Lytle, and D. Moe. 1971. Climate of South Dakota. South Dakota State Univ., Agric. Exp. Sta. Bull. 582. 30 pp.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York. 481 pp.

Taverner, P. A. 1934. Birds of Canada. Natl. Mus. of Canada. Biol. Ser. No. 19. Bull. 72. Ottawa, Ontario. 445 pp.

U.S. Department of Agriculture. 1976a. Soil Conservation Service, Family of Maps, SCS Drawing No. 5, S-32, 929. Lincoln, Nebraska.

U.S. Department of Agriculture, Forest Service. 1976b. Environmental Statement, Sioux Planning Unit, Multiple Use Plan. 129 pp.

U.S. Department of Agriculture, Soil Conservation Service. 1977. Estimated Land Use Conversions. 32 pp.

U.S. Department of Interior. 1968. Rare and endangered fish and wildlife of the United States. Res. Pub. 34. U.S. Government Printing Office, Washington, D.C. 47 pp.

U.S. Department of Interior, Geological Survey. 1970. The National Atlas of the United States of America. 417 pp.

Ward, B. 1968. Wyoming's ground nesting hawks. Wyoming Wildlife 32(4):15-17.

Westin, F. C., G. L. Buntley, and L. F. Puhr. 1967. Soils of South Dakota. South Dakota State Univ., Agric. Exp. Sta. Soil Survey Ser. No. 3. 32 pp.

Weston, J. B. 1969. Nesting ecology of raptorial birds in central Utah; Nesting ecology of the ferruginous hawk Buteo regalis. Brigham Young Univ. Sci. Bull. Biol. Ser. 10(4):25-36.

_____ and D. Ellis. 1968. Ground nesting of the ferruginous hawk in west-central Utah. Great Basin Nat. 28(2):111.

Woffinden, N. D. 1975. Ecology of the ferruginous hawk (Buteo regalis) in central Utah: population dynamics and nest site selection. Ph.D. Diss. Brigham Young Univ., Provo, Utah. 102 pp.