Ferruginous hawk and prairie falcon reproductive and behavioral responses to human activity near the Kevin Rim, Montana
by Russell Carl Van Horn

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

Abstract:
The reproductive and behavioral responses of nesting ferruginous hawks (Buteo regalis) and prairie falcons (Falco mexicanus) and the behavioral responses of roadside foraging raptors to human activity and artifacts were studied on a 148 km2 study area near Kevin, Montana during the 1991 and 1992 nesting seasons. Thirty-four ferruginous hawk and 24 prairie falcon breeding sites were occupied during the study. Ferruginous hawk and prairie falcon site occupancy was not significantly influenced by the presence of powerlines, roads, or active oil wells. Ferruginous hawks nested primarily on outcrops and cliffs (54%) or elevated ground sites (42%) and were clumped along the Kevin Rim, a prominent sandstone escarpment. Ferruginous hawk nesting density (8.4 km2 /pair) was among the highest reported in the literature, but productivity was relatively low (47% success, 1.1 fledglings/occupied nest). The primary cause of ferruginous hawk pre-dispersal mortality was wet weather, which caused 37% of all losses. The local ferruginous hawk population may not be able to sustain itself at current levels if wet weather patterns continue to destroy nests and young. Prairie falcon productivity was also relatively low (71% success, 1.9 fledglings/occupied nest) but appeared sufficient to maintain the population. There was no significant difference between ferruginous hawk or prairie falcon reactions to intrusion in areas with petroleum development. Ferruginous hawks in the Kevin Rim area were quicker to respond to human activity than ferruginous hawks in other studies, which may have been due to past human activity levels or reduced prey availability. Foraging ferruginous hawks avoided humans more than Swainson's hawks (Buteo swainsoni), northern harriers (Circus cyaneus), or red-tailed hawks (Buteo iamaicensis). In spite of this, ferruginous hawks still foraged along secondary roads in oilfields more than expected. Human activity in the area affected only a fraction of the local ferruginous hawk and prairie falcon breeding populations.

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APPROVAL

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Russell Carl Van Horn

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

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Date 20 September 1993

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ABSTRACT

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INTRODUCTION

The Kevin Rim, a sandstone escarpment in north-central Montana, supports one of the highest nesting densities of grassland raptors in western North America (Dubois 1988, Harmata et al. 1991). The Kevin Rim Special Management Area has been declared a Key Raptor Area by the Bureau of Land Management (BLM), where "unusually high nesting populations occur resulting from special habitat features" (Olendorff et al. 1989:21). Ferruginous hawks (Buteo regalis) and prairie falcons (Falco mexicanus) are common breeders in the area and golden eagles (Aquila chrysaetos) and burrowing owls (Athene cunicularia) also nest in the area. These raptors are considered Species of Special Concern in Montana (Flath 1984). Nesting ferruginous hawks may be especially sensitive to disturbance (Fyfe and Olendorff 1976). In addition, the ferruginous hawk is classed as a Category II species (species of high national concern) by the U.S. Fish and Wildlife Service (USFWS) and was on the Audubon Society's Blue List (declining species vulnerable to extinction) from 1971 to 1986 and has since been a Species of Special Concern to that organization (Tate 1986). Some researchers believe populations have increased since 1980 (Warkentin and James 1985, Gossett and Bechard 1992), but others disagree (National Audubon Society 1992, A.R. Harmata pers. commun.).

Petroleum extraction and agricultural activities have occurred on and around the Kevin Rim for decades (Perry 1953) and may affect local raptor populations. I had 6 primary objectives regarding raptors nesting in the Kevin Rim area but emphasized breeding ferruginous hawks and prairie falcons. The objectives were: 1) locate all occupied ferruginous hawk and prairie falcon breeding sites and monitor their productivity, 2) determine impact of human activities on site occupancy and productivity, 3) document reaction to humans of breeding ferruginous hawks and prairie falcons, 4) evaluate use of surrounding areas by foraging ferruginous hawks and prairie falcons, 5) measure reaction to humans of foraging ferruginous hawks and prairie falcons, and 6) develop management recommendations for the Kevin Rim area.

STUDY AREA

Location and Land Ownership

The 148 km^2 study area was located northwest of the town of Kevin in Toole County, Montana (Fig. 1). Elevations ranged from 1013 m to 1310 m above sea level. Topography varied from alkali flats in the southeast to hills and ravines in the north and sandstone escarpments in the west. Several springs, numerous ephemeral wetlands, scattered livestock reservoirs, and 2 freshwater ponds (< 0.5 km^2) were the only freshwater sources.

I divided the study area into 3 units for this study (Fig. 1). The northern badlands and the adjacent section of the Kevin Rim were designated as the "reference unit" (43.8 km^2). This unit corresponded to the Badlands control area of Harmata et al. (1991). The alkali flats, the southern portion of the Kevin Rim and rolling areas immediately west of the cliffs were designated as the "developed unit" (88.1 km^2). This approximately corresponded to the experimental area of Harmata et al. (1991). Rolling grasslands and low (< 20 m) rock outcrops adjacent to the southwest end of the Kevin Rim were designated as the study area "extension" (16.0 km^2).

Geology

The Kevin Rim is composed of Eagle (Virgelle) sandstone, an Upper Cretaceous sediment overlaying petroleum-bearing Lower Cretaceous and

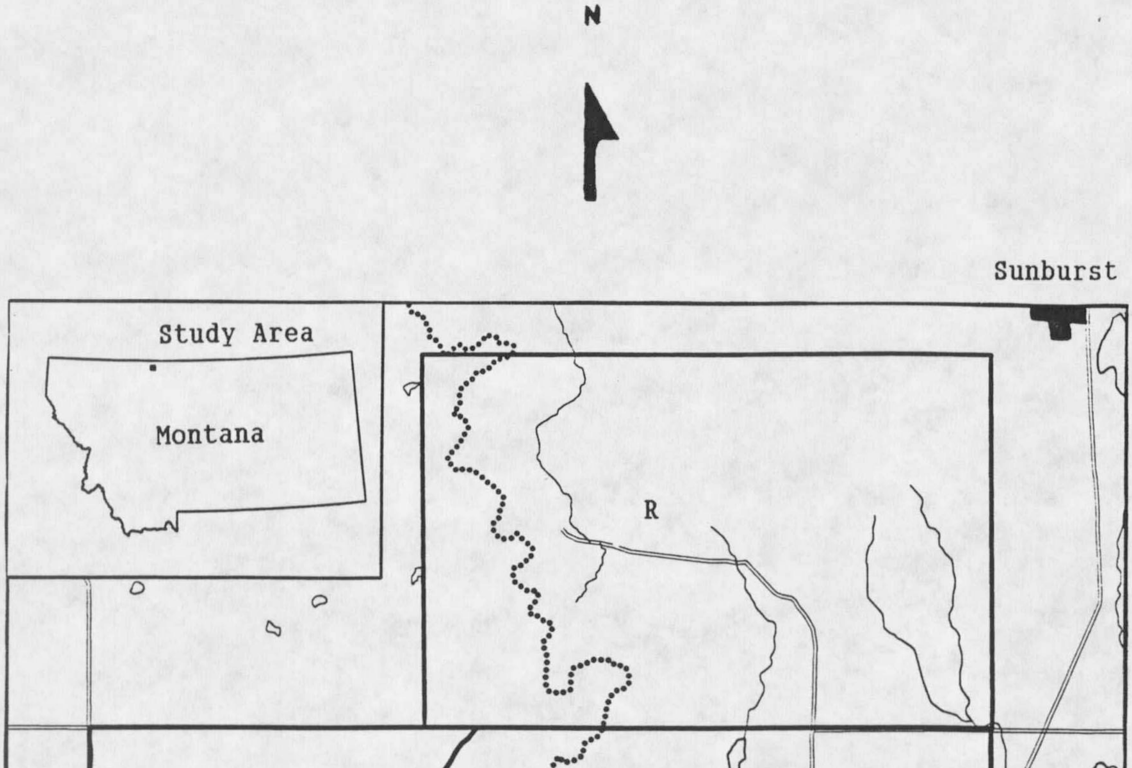

Figure 1. Road distributions in the developed (D), reference (R), and extension (E) units of the Kevin Rim study area, Montana, 1991 and 1992. Thick lines indicate unit boundaries, double lines represent roads, and the dotted line indicates the edge of Kevin Rim.

Mississippian sediments. The rim is part of the Sweetgrass Arch, a large anticlinal fold (Perry 1953). Cliffs vary from 6-35 m tall in the developed unit, from 6-12 m tall in the reference unit, and are approximately 6 m tall in the study area extension. Erosion since the last glaciation (17,000 years ago) formed sandy and clayey alluvial fans, created talus slopes, and downcut ravines (Hollin and Schilling 1981).

Climate and Weather

The Kevin area has an average of <100 days between the last spring and first autumn frost (U.S. Dept. Commerce 1973:67). There were 97 days between frosts in 1991 and 92 days in 1992. Between 70% and 80% of annual precipitation falls during summer, most often as afternoon thunderstorms in June. Long-term (1951-1980) average annual precipitation at Sunburst, 2 km northwest of the reference unit, is 29.3 cm (U.S. Dept. Commerce 1991, 1992). Winds are predominantly from the southwest throughout the year and are calm for only 2 hours per day (U.S. Dept. Commerce 1973:86, 87).

Although precipitation totals were similar, climatological conditions varied from 1991 to 1992. Except for July, the summer of 1991 was wetter than usual (Table 1). June 1991 was the second wettest on record for the area (U.S. Dept. Commerce 1991). The summer of 1992 was also wetter than average (121%) but not as wet as 1991 (131% of average) (Table 1). April and June were much drier than in 1991 but this was nearly balanced by thunderstorms on 5, 10, and 29 July (Table 1). July 1992 was the coldest recorded for this area and had 15 days of precipitation. The first snowfall of autumn 1992 took place on 22 August, more than a month earlier than in 1991 (U.S. Dept. Commerce 1991, 1992).

Table 1. Monthly and annual precipitation totals (cm), departures from average (cm), days of precipitation, and mean temperature (°C) for Sunburst, Montana, 1991 and 1992.[a]

year		Apr	May	Jun	Jul	Aug	Apr-Aug	annual
1991	ppt	3.61	5.69	13.92	0.15	5.16	28.52	36.12
	dep	1.30	0.66	7.01	-3.66	1.45	6.76	5.79
	wetdays	4	6	12	1	9	32	54
	temp	6.78	10.78	13.83	19.11	21.22	14.40	7.11
1992	ppt	2.64	3.23	7.49	8.71	4.19	26.26	35.76
	dep	0.33	-1.80	0.58	4.90	0.48	4.50	6.45
	wetdays	5	5	8	15	6	39	62
	temp	8.22	13.06	17.28	15.61	17.17	11.24	9.19

[a] Data from U.S. Dept. Commerce 1991, 1992

Vegetation

DeVelice (1990) described the plant communities in the study area. The most common vegetative associations were grasslands dominated by bluebunch wheatgrass (*Agropyron spicatum*), western wheatgrass (*Agropyron smithii*), blue gramma (*Bouteloua gracilis*), fringed sagewort (*Artemisia frigida*), and Sandberg's bluegrass (*Poa sandbergii*). The sparse vegetative cover in the badlands consisted of Nuttall's saltbrush (*Atriplex nuttallii*), Indian ricegrass (*Oryzopsis hymenoides*), bluebunch wheatgrass, and silver sagebrush (*Artemisia cana*) (DeVelice 1990).

Shrub associations, dominated by silver sagebrush, chokecherry (*Prunus virginiana*) or snowberry (*Symphoricarpos occidentalis*), were found in riparian areas, as were forest associations dominated by cottonwood (*Populus deltoides*) and aspen (*Populus tremuloides*). Common understory plants in the latter associations were chokecherry, juneberry (Amelanchier alnifolia), red osier dogwood (Cornus stolonifera), and swamp currant (Ribes lacustre). Small stands of creeping juniper (Juniperus horizontalis) were occasionally found just below the rimrock.

Wildlife

Seventeen species of mammals were observed on the area (Appendix A Table 7). The only common native ungulate was the mule deer (Odocoileus hemionus). Evidence of red fox (Vulpes vulpes) was more common than evidence of any other carnivore or omnivore. Yellow-bellied marmots (Marmota flaviventris) were common along the cliffs. Numerous Richardson's ground squirrels (Spermophilus richardsonii) were located on the developed and extension units. White-tailed jackrabbits (Lepus townsendii) and desert cottontail rabbits (Sylvilagus audubonii) were also present in these units but were less common. Very few small mammals were seen on the reference unit.

Ten species of raptors and 42 other bird species were seen on the study area. Nine raptors and 31 other species were known or suspected to breed on the area (Appendix A Table 8). The most common breeding raptors on the area were ferruginous hawks, prairie falcons, great horned owls (Bubo virginianus), and American kestrels (Falco sparverius).

Human Impacts

The study area was occupied by Piegan Blackfeet prior to European settlement. Numerous tepee rings and 2 or 3 "buffalo jumps" were recorded by European settlers. European settlement began in 1890 with the establishment of a sheep ranch east of the Kevin Rim. Sheep ranching became the dominant land use; by the 1930's there were more than 50,000 sheep in the Kevin Rim area. The importance of sheep ranching declined by the 1950's; by 1976 there were <2,300 sheep in the area (Prairie Homemaker's Home Extension Club et al. 1976:12, 37, 39).

The discovery well of the Kevin-Sunburst oil field was completed in 1922 approximately 7 km northwest of the present town of Kevin. By the end of 1928, >1,600 wells had been drilled within 19 km south and east of Kevin (Perry 1928).

Intensive petroleum extraction in the developed unit began around 1946. In 1951, 1,861 of 2,586 wells were active in the Kevin-Sunburst oil field (Perry 1953). Oilfield activity declined after the 1950's, except for a short boom in the late 1960's and early 1970's. There were 100 active wells on the developed unit in 1991 and 122 in 1992. Twelve wells were active on the reference unit in both years. There were no active wells on the extension unit in either year.

Activities associated with petroleum development include daily maintenance of pumping rigs, drilling of new wells, and reactivation of inactive wells. Physical structures associated with petroleum development include oil pumps, water evaporation tanks and ponds, oil storage tanks, pipelines, power lines, and roads.

There were 3 classes of roads in the study area. Primary roads were paved or graded gravel county roads and received most use. Secondary roads were gravel township roads that received intermediate use. Tertiary roads were unimproved roads which varied in use from daily to semi-annually. There were approximately 215 km of roads in the study area including 6.6 km of primary roads, 16 km of secondary roads and 192.3 km of tertiary roads. Road densities for the 3 units are shown in Appendix B Table 9, with primary and secondary road distributions presented in Figure 1.

The human populations of Kevin and Sunburst have steadily declined since 1960. In 1990, approximately 664 people lived within a 3.57 km radius of the Kevin Rim (Kevin, Oilmont, Sunburst) for an average density of 16.59 people/km^2 (Bur. of Census 1990).

METHODS

Field work was conducted from 15 May to 16 August 1991 and from 16 May to 13 August 1992. This encompassed the raptor breeding season from the middle of ferruginous hawk incubation and beginning of the prairie falcon nestling period to the post-fledging period of both.

Nest Searches and Documentation

The area was systematically searched on foot for raptor breeding attempts at the start of each field season with greater emphasis placed on historically occupied ferruginous hawk and prairie falcon breeding sites. Nest structures and eyrie locations were plotted on United States Geological Survey (USGS) 1:24000 topographic maps. Site substrates were visually classed as cliff (stone formation >4 m tall), outcrop (stone formation <4 m tall), vegetation, ground, or structure. Sites were classed as unoccupied, occupied, active, or supernumery based on the terminology of Weston (1969) and Postupalsky (1974). Nests were considered occupied if freshly repaired or if 2 adults were seen defending the site vicinity. After all sites were plotted, map measurements were used to calculate 5 dispersion distances for all nests and eyries: distance to nearest powerline, nearest road, nearest active oil well or tank, nearest occupied site of the same species, and nearest occupied site of another diurnal raptor larger than an American kestrel or burrowing owl.

Clark and Evans' (1954) ratio of expected and observed distances between nearest conspecific nests was calculated to allow comparison of ferruginous hawk nest dispersion in the study area with that found in past studies. R is 1.0 when nests are randomly spaced. Departures from 1.0 indicate clumping of nests ($R < 1.0$) or uniform spacing of nests ($R > 1.0$). Nestlings were aged using photographic guides for aging ferruginous hawks and prairie falcons (Moritsch 1983, 1985).

Nest Defense and Reproductive Success

Occupied breeding sites were visited every 5-10 days. Sites were initially observed at the greatest distance possible with a 45X spotting scope and the number of young present was recorded. The observer would then approach the breeding site on foot in a zig-zag pattern as allowed by terrain, until the attending adult(s) flew. Horizontal and vertical distances from the observer to the site were estimated from USGS 1:24000 topographic maps and were recorded during 3 instances: when the adult first exhibited any reaction to the intrusion, when the bird first called, and when it flew to begin defending the nest. The observer then left the vicinity. Site intrusions were suspended for approximately 1 week when nestlings were nearly fledged to avoid causing premature fledging. Post-fledging site visits measured the distances from observer to nearest fledgling. No site intrusions were made during cool (<10° C) or wet weather.

Number, gender, and color phase of ferruginous hawk nestlings were recorded while performing nest intrusions. Nestling gender was determined by tarsal measurements during leg banding of nestlings ≥30 days old. Fledglings which required USFWS leg bands >7B were considered females, with all others classed as males. The Mayfield estimate of nest success was calculated from nest defense observations. This method was used to compensate for late initiation of field work in both seasons (Steenhof and Kochert 1982).

Banding and Radio-telemetry

Inclement weather prevented the banding of nestlings in 1991. In 1992, 21 nestling ferruginous hawks and 1 nestling Swainson's hawk Buteo swainsoni) were banded on the right leg with USFWS lock-on aluminum leg bands. In addition, 1 adult male prairie falcon, 1 nestling female prairie falcon, and 1 adult female ferruginous hawk were banded and fitted with radio transmitters.

Both adult birds were captured near their breeding sites with a dho-ghaza net baited with a live great horned owl (Meredith 1969). Bal-chatris (Berger and Mueller 1959) baited with Richardson's ground squirrels and white-tailed jackrabbits were not effective in capturing nesting adults. Radio-tagged birds were released at their capture sites.

Transmitters were mounted as backpacks with lateral straps of teflon ribbon passing anteriorly and posteriorly to each humerus. Transmitter frequencies were 148.018, 148.066, and 149.097 Megahertz (MHz). Transmitters were monitored with vehicle mounted omni-directional whip antennas and hand-held 3-element Yagi antennas. Triangulation bearings were taken every 15 minutes by 2 observers during 4 time periods (0530-0900, 0900-1230, 1230-1600, and 1600-1930).

Adult Mortality

Searches of nest site vicinities were conducted to determine the fate of any missing young. All powerlines in the area (42.9 km) were searched monthly from May to August in both years for evidence of raptor electrocution and nesting attempts. The circumstances involving any dead raptors seen in the study area were investigated.

Foraging Habitat Use and Reactions to Human Presence

Habitats were classed into 4 land-use classes: rangeland, fallow agricultural field which includes fallow wheat (*Triticum vulgare*) fields and Conservation Reserve Program (CRP) lands, agricultural field, and oilfield (within approximately 100 m of an oil well or tank). Forty-one kilometers of roads in the 4 land-use classes were driven every 10 days from 1 July to 12 August each year. Routes were driven at 48 km/hr during the morning (0630-0930), mid-day (1200-1500), and evening (1830-2030). Descriptive measurements were recorded for every identifiable raptor (to nearest meter). Measurements included local land use class, type of perch used (if applicable), horizontal distances from the raptor to road and to human activity, reaction of the bird to passing vehicle, and (when pertinent) distance the bird flew from its perch as a result of vehicle passing. Each raptor was then approached by vehicle (if perched $\leq$5 m from road) or on foot (if perched >5 m from road) until the bird reacted. The observer stopped for 30 seconds every 5 m to note the raptor's behavior. Similar observations were conducted on raptors seen while conducting other field activities.

Prey Availability

Headlight surveys on 20.9 km of roads were conducted approximately one hour after sunset every 2 weeks from 1 June to 12 August as described in Harmata et al. (1991). Every lagomorph seen while driving at 48 km/hr was recorded at the end of every survey mile.

In 1991, 5 concentrations of Richardson's ground squirrels were surveyed every 2 weeks from 9 June to 13 August. In 1992, surveys of an additional site were included. Surveys were conducted in mid-morning (0800-0930), mid-afternoon (1330-1500), and early evening (1800-1930). After remaining motionless for 5 minutes, the observer would record the total number of ground squirrels visible during the next 5 minutes as an index of ground squirrel availability as prey for diurnal raptors. Neither lagomorph nor ground squirrel surveys were conducted within 1 hour after rainfall because of road conditions.

Human Oilfield Activity

A local contractor provided information on the amount of time spent on oil well inspection, maintenance, and servicing on a 19-well lease in the oilfields during June 1991. This information was extrapolated to the entire oilfield.

Data Analysis

Unless otherwise stated, level of rejection for all significance tests was $\alpha = 0.10$. Non-parametric tests were used with small samples and non-normal data [as revealed by high degrees of skewness and kurtosis and low Shapiro-Wilk probabilities (Shapiro and Wilk 1965)].

As suggested by Daniel (1990), the Moses test for equal variances was used to determine if the Mann-Whitney median test was appropriate for comparing nest defense measurements, nest dispersion measurements, and ground squirrel indices. Dispersion measurements of occupied ferruginous hawk nests were compared with those of unoccupied nests instead of random points because pre-existing nest structures were assumed to be available and suitable for ferruginous hawk nesting, but random points might be unsuitable for reasons not considered in this study (i.e. exposure, aspect). Nest defense measurements were also analyzed for trend (increasing or decreasing) with Cox-Stuart tests (Daniel 1990). When rejection of null hypotheses (equal variances) under Moses tests did not permit use of Mann-Whitney tests, median tests were used (Daniel 1990). Use of different nest substrates by ferruginous hawks was compared with pre-existing nest structures by using a chi-square test. Percent of occupied nests successful was compared between units and years with Fisher's exact tests (Daniel 1990) and the number of fledglings per occupied nest was compared among units and years with Kruskal-Wallis tests (Daniel 1990). Results of lagomorph surveys were nearly identical between years so were not further analyzed.

Road survey data were analyzed with chi-square tests to compare observed road and habitat use with random use. Observed rates of perch use by raptor species were compared with chi-square homogeneity tests. Group confidence intervals were constructed for observed use rates of each road and habitat type. These confidence intervals were compared with expected use rates to determine which, if any, categories were responsible for rejection of chi-square null hypotheses (Neu et al. 1974). The median and 3 percentiles (75%, 90%, 95%) were calculated for all horizontal defense measurements and nest dispersion measurements.

RESULTS

Nest Substrates

Ninety-eight ferruginous hawk nest structures were identified in the study area (Appendix B Table 10). Forty-three were ground nests, 30 were on rock outcrops, 24 were cliff nests, and 1 was on top of a grain bin. The 26 nests which were occupied at least once did not differ significantly ($P > 0.10$) in substrate frequency from previously constructed structures. Exact territorial boundaries were not determined but there was an average of 4.8 supernumery nesting structures per occupied nest. Nest structures and occupied nests were associated with the escarpment significantly more than predicted by chance ($P < 0.005$).

Site Occupancy and Reuse

Ferruginous hawks and prairie falcons were the most common raptors nesting in the study area (Appendix E). After applying the Mayfield method to observed nest data, there were 14 ferruginous hawk nests and 12 prairie falcon eyries occupied in 1991. In 1992, there were 20 ferruginous hawk nests and 15 prairie falcon eyries occupied.

Five of 8 successful (≥1 fledgling) ferruginous hawk nests in 1991 were also used in 1992, which is a slightly higher rate of reuse than for unsuccessful (2 of 5) nests. I was unable to pinpoint the location of some prairie falcon eyries and will, therefore, comment only on reuse of cliff sections (≤20 m long). Twenty prairie falcon eyries or eyrie cliffs were identified during the study. All 12 sites occupied in 1991 were used in 1992 even though 4 of them were unsuccessful in 1991.

Unoccupied and occupied ferruginous hawk nests did not have significantly different median distances to nearest powerlines ($0.472 > P > 0.468$), roads ($P = 0.95$), active oil wells ($P = 0.47$), or occupied nests of other raptor species ($P = 0.15$) (Appendix B Table 11). Unoccupied ferruginous hawk nests were significantly closer to occupied ferruginous hawk nests than occupied ferruginous hawk nests were to each other ($P < 0.005$) (Appendix B Table 11).

Occupied ferruginous hawk nests on the escarpment were, on average, 0.3 km apart. Nearly all (143 km^2) of the study area was considered suitable for ferruginous hawk nesting. There was an average of 1 occupied nest per 8.41 km^2. Nest locations indicated significant clumping ($R = 0.65$, $P = 0.0008$).

Unoccupied and occupied prairie falcon eyries did not have significantly different median distances to nearest powerlines ($P > 0.2$), roads ($P > 0.2$), active oil wells ($0.2 > P > 0.1$), nests of other raptor species ($P > 0.2$), or occupied prairie falcon eyries ($P > 0.2$) (Appendix B Table 11).

There were 22.3 km of cliffs in the study area which were considered suitable for prairie falcon nesting, with an average of 0.605 nests/km of cliff. Occupied prairie falcon nests were significantly more uniformly spaced than random ($R = 3.72$, $P < 0.0001$).

Occupied ferruginous hawk nests were significantly farther ($P < 0.1$) than occupied prairie falcon eyries from the nearest powerline, road, active oil well, nest of other raptor species, or nest of the same species (Table 2).

Table 2. Distances (km) from ferruginous hawk and prairie falcon breeding sites to the nearest sources of human activity and occupied raptor sites on the Kevin Rim study area, Montana, 1991 and 1992.

	Distance			Percentile		
Activity	mean	SD	median	75th	90th	95th
Ferruginous Hawk nests (N=98)[a]						
Powerline	2.4	1.9	2.0	3.6	5.2	5.8
Road	0.5	0.3	0.4	0.7	0.8	1.1
Oil well	1.5	0.9	1.1	1.9	3.5	3.6
Other species	0.7	1.1	0.5	1.9	1.3	3.0
Same species	1.0	0.5	1.1	1.4	1.7	1.8
Prairie Falcon eyries (N=20)						
Powerline	1.7	2.1	0.9	1.3	5.9	6.8
Road	0.4	0.3	0.3	0.5	0.8	0.8
Oil well	0.9	0.4	1.0	1.2	1.3	0.7
Other species	0.3	0.2	0.3	0.4	0.5	0.7
Same species	0.6	0.4	0.5	0.6	1.2	1.2

[a] Distance to same species nest is only from occupied nests (N=25), unoccupied nests had a significantly different median (0.54 km, $P<0.005$).

Reactions to Breeding Site Intrusions

Attending adults never left the breeding site vicinity while an intrusion was occurring. Nesting ferruginous hawks commonly responded to humans by flying from their perch toward the intruder, circling over the intruder and occasionally calling. If intrusion neared the nest, 1 or both adults would usually dive to within 5 m of the intruder. Diving birds never struck the intruder(s).

Nesting ferruginous hawks in the developed and reference units did not have significantly different median distances within or between years at which they first reacted, first flew, or first called (Appendix B Table 12) nor did these distances show a significant trend over time ($P > 0.1$). Ferruginous hawks first responded to human intrusion when the observer was, on average, 205 m from the nest (Table 3).

Table 3. Distances (m) at which ferruginous hawks and prairie falcons reacted in response to a human intruder near their breeding sites on the Kevin Rim study area, Montana, 1991 and 1992.

	Distance				Percentile		
Response	N	mean	SD	median	75^{th}	90^{th}	95^{th}
Ferruginous Hawks							
First reaction	91	205.5	162.1	160	300	495	532
Flushed	87	202.8	157.4	160	280	430	532
Called	79	185.5	138.2	60	260	400	495
Prairie Falcons							
First reaction	87	95.2	66.8	75	120	200	266
Flushed	86	79.0	58.7	63	90	150	200
Called	74	97.2	72.8	75	140	210	266

Prairie falcons often reacted to intrusion at the eyrie by first calling from a perch and then flying to circle and dive at the intruder. There were no recorded instances of falcons striking intruders. Prairie falcons reacted much more vigorously to a great horned owl used in a dho-ghaza, diving in rapid succession until either the falcon was trapped or the owl was removed.

Breeding prairie falcons in developed and reference units did not have significantly different median distances between or within years at which they first flew or first called. There was no significant difference between units within years in median first reaction distances, but the median distance of first reaction observed in the developed unit during both years was significantly different ($P = 0.003$) from the median distance of first reaction in the reference unit during both years (Appendix B Table 13). Although median differences were statistically significant, I believed the difference (2.5 m) was biologically insignificant relative to possible measurement errors and therefore combined these measurements. Prairie falcons first responded to human intrusion when the observer was, on average, 95 m from the eyrie (Table 3). There was no significant trend ($P > 0.1$) in response distances through the breeding season. Prairie falcons allowed intruders to approach the nest significantly closer than did ferruginous hawks before reacting ($P < 0.005$) and flushing ($P < 0.005$) but called when intruders were significantly farther away ($P < 0.0002$).

Reproductive Success

In 1991, ferruginous hawks had greater reproductive success in the reference unit (5 of 7) than in the developed unit (3 of 7), but the difference was not significant ($P = 0.25$) (Table 4). In 1992, ferruginous hawks in the reference unit had lower success (5 of 9) than those in the developed unit (7 of 11), but this difference was also not significant ($P = 0.36$). When 1991 and 1992 data were combined, reproductive success was greater in the reference unit (63%) than the developed unit (56%), but the difference was not significant ($P = 0.17$).

Ferruginous hawk brood sizes ranged from 1 to 4 in 1991 ($\bar{x}=2.5$, SD=1.02) and 1992 ($\bar{x}=2.8$, SD=0.80) and the number fledged per successful nest ranged from 1 to 4 in 1991 ($\bar{x}$=2.6, SD=0.86) and 1992 ($\bar{x}$=2.0, SD=0.83).

Table 4. Mayfield productivity and success estimates and the known pre-dispersal mortality rates[a] for ferruginous hawks and prairie falcons on the Kevin Rim study area, Montana, 1991 and 1992.

Species	Year	# of nests occupied	# of nests successful	Success rate	# of young fledged	Known mortality rate
Ferruginous Hawks	1991	14	8	0.57	21	0.31
	1992	20	8	0.40	16	0.43
Prairie Falcons	1991	12	8	0.66	22	0.04
	1992	15	11	0.73	29	0.07

[a] This is a conservative estimate of the actual mortality rate since there may have been unobserved mortalities.

In 1991, prairie falcons had higher reproductive success in the reference unit (3 of 3) than prairie falcons in the developed unit (5 of 9) but the difference was not significant (P = 0.26). In 1992, prairie falcons again had a higher success rate in the reference unit (3 of 3) than developed unit (8 of 10) but this difference also was not significant (P = 0.58). When data from both years were combined, the reference unit success rate (100%) was higher than the developed unit success rate (68%) but the difference was not significant (P = 0.15).

Prairie falcon brood sizes ranged from 2 to 4 in 1991 ($\bar{x}$=3, SD=1.0) and from 1 to 5 in 1992 ($\bar{x}$=2.6, SD=1.11). The number fledged per successful nest ranged from 1 to 4 in 1991 ($\bar{x}$=2.8, SD=0.83) and from 1 to 5 in 1992 ($\bar{x}$=2.5, SD=1.12).

Breeding Phenology

Dates of egg laying, hatching, and fledging were estimated by back-dating from nestlings' ages at first observation (Table 5).

Table 5. Estimated egg laying, hatching, and fledging dates for ferruginous hawks and prairie falcons on the Kevin Rim study area, Montana, 1991 and 1992.

	Ferruginous hawk		Prairie falcon	
Event	1991	1992	1991	1992
Egg laying	4/20-5/05	4/22-5/05	4/13-5/08	4/11-4/25
Hatching	5/20-6/04	5/22-6/04	5/13-6/07	5/11-5/25
Fledging	7/04-7/19	7/06-7/19	6/20-7/15	6/18-7/03

Fledgling Movements

Ferruginous hawk fledglings (N = 19) stayed within 500 m of the nest for an average of 16.3 days (SD=17.5) after fledging. Length of this period varied from nest to nest and among nest mates and ranged from 2 to 57 days. Fledglings were seen within the study area for at least 76 days after the last known fledging. Prairie falcon fledglings stayed within 500 m of the eyrie for an average of 17.1 days (SD=8.7) after fledging. Length of this period ranged from 6 to 34 days, which also encompassed the period in which prairie falcon fledglings were seen in the study area. It was not always known if ferruginous hawk and prairie falcon fledglings seen in the area were unbanded local young (Appendix D) or immigrants from other areas.

Telemetry

An adult female ferruginous hawk was captured and fitted with a radio on 11 June 1992 and was subsequently monitored for 13.5 hours over 8 days. At the time of capture she was defending a ground nest containing 3 nestlings (approximately 19 days old) in the oilfield. She foraged within 1.2 km of the nest in rangeland and oilfield habitats but spent most of her time within sight of the nest. Following several days of rain in late June, searchers failed to locate any sign of the nestlings in the vicinity on 2 July. The female was mildly defensive but showed less fidelity to the nest site over the following week and began roosting for the night on a ridge 1.6 km from her nest in the oilfield. On 15 August she was recaptured following 2 days of reduced movement and was found to be thin and dehydrated with the transmitter twisted laterally and turned anterio-posteriorly. This tightened the straps and cut deeply into muscles at the base of the left humerus. She was euthanized after rehabilitation failed.

An adult male prairie falcon defending a brood in the developed unit was captured and fitted with a radio on 12 June 1992 and monitored for 10 hours over 6 days before the signal was last received on 9 July. Subsequent intensive searching failed to locate either the bird or the transmitter. During the period he was monitored, this falcon foraged in rangeland habitats and was never located or seen within 50 m of a road.

A nestling female prairie falcon was fitted with a radio on 18 June 1992 and subsequently monitored for 9.25 hours over 6 days. After fledging, this bird and 2 (of 3) unbanded siblings spent nearly all of their time on ridgetops along the edge of the oilfield, roosting in the same vicinity every evening. A favored perch site was visible from a tertiary road, so radio locations were often not necessary. On 5 August the radio signal was permanently lost. Searchers discovered only the remains of an unbanded juvenile prairie falcon.

Mortality

Mortality rates were not significantly different ($P > 0.1$) between units and years for ferruginous hawks or prairie falcons (Table 4). Avian predation was responsible for 27.9% of all ferruginous hawk nestling and fledging mortality. Three ferruginous hawk fledglings were lost each year to great horned owl predation at the same cliff nest site. Owl predation was inferred from the presence of owl pellets near ferruginous hawk feathers on nearby ledges in 1991 and by observations of 2 owls in the vicinity of ferruginous hawk remains and leg bands (Appendix D) in 1992. An unknown avian predator was suspected in the 1992 death of a fledged prairie falcon discovered while radio-tracking.

Mammalian predation was responsible for 23.3% of all ferruginous hawk nestling and fledging mortality. Mammalian predators ate the only 2 eggs in one ferruginous hawk ground nest and the only nestling from another ferruginous hawk ground nest in 1991. One pair of prairie falcons were vigorously harassing a yellow-bellied marmot adjacent to their eyrie on 24 May 1991. After that date this pair of falcons gradually became less defensive and eventually abandoned the eyrie. In 1992 all 3 nestling ferruginous hawks in a ground nest were killed by a coyote (<u>Canis latrans</u>). A pair of prairie falcons spent >2.5 hours on 21 May 1991 harassing a pair of golden eagles which were occupying a nest >50 m from the eyrie. The day was cold and windy and neither site was defended for more than a week after this. Two newly fledged prairie falcons were found dead and uneaten within 50 m of a strongly defended red-tailed hawk cliff nest in 1992.

Cold, wet weather was responsible for 37.2% of all ferruginous hawk nestling and fledgling mortality and was a major cause of ferruginous hawk nestling mortality in 1992. One outcrop nest in the reference unit collapsed prior to 1 June but was weakly defended for another week. Two cliff nests in the reference unit collapsed after becoming saturated during a period of heavy rain and hail in late June killing all (≥3) nestlings in them. During this same period, all 3 nestlings from a ground nest in the developed unit vanished and 2 of 3 nestlings from a ground nest in the reference unit appear to have starved.

In 1991, 4 ferruginous hawk pairs lost some or all of their nestlings to unknown causes for a total loss of ≥6 nestlings. One of these nestlings was found intact in the nest, as were 2 nestlings from 2 ferruginous hawk nests (containing 2 and 3 nestlings) in 1992. Also in 1992, an entire ferruginous hawk brood of 3 nestlings over 24 days old was lost to an unknown cause.

On 4 July 1991, I found an unbanded adult golden eagle electrocuted under a power pole (UTMN 5401.20, UTME 426.25). I had often seen ferruginous hawks perched on this pole, which overlooked a Richardson's ground squirrel colony. An unbanded subadult golden eagle was found electrocuted under the adjacent powerpole on 31 July. These poles were modified (longer cross arms, superior perch) in the autumn of 1992 by the Marias River Electric Cooperative.

An adult prairie falcon was found dead along a paved road in 1991. It was apparently the victim of an automobile impact, but the remains were too decomposed and crushed to rule out shooting. In 1992, an adult ferruginous hawk was found freshly killed by collision along the same road. Severe abrasions and broken bones were evident and no bullet wounds were apparent.

Foraging Perch Use, Habitat Use, and Response to Humans

Ferruginous hawks perched on outcrops and the ground significantly more and on fenceposts significantly less than other roadside foraging raptors (Appendix B Table 14, Appendix E Table 19).

Ferruginous hawks did not use roads or roadside habitats in proportion to their availability. Ferruginous hawks were seen near secondary roads significantly more than expected and primary and tertiary roads significantly less than expected (Appendix B Table 15, Appendix E Table 20). Ferruginous hawks used fallow lands significantly less and oilfields significantly more than expected (Appendix B Table 15, Appendix E Table 21). Ferruginous hawks showed the greatest variation in response and had the largest median flushing distance to humans, 35 m, of the 4 raptors commonly seen along roadsides (Appendix E Table 22). There were too few sightings of prairie falcons (N = 10) for these comparisons. All roadside raptors flew away from the human activity without showing defensive behavior (i.e. circling and diving).

Prey Availability

I saw a total of 18 white-tailed jackrabbits and 6 desert cottontail rabbits (Sylvilagus audubonii) during lagomorph headlight surveys (N = 6) in 1991. In 1992, I saw 6 jackrabbits and 5 cottontails along the same routes (N = 6). Land use along survey routes did not change between the 2 years and the decline between years was an artifact of the change in average number of lagomorphs/km along route 1 from 1.69 in 1991 to 0.34 in 1992. The average number of lagomorphs/km declined slightly along route 2 from 0.34 in 1991 to 0.30 in 1992.

Although there were no significant differences between the number of Richardson's ground squirrels seen at different times of the day during both summers, more ground squirrels were seen in the morning than at mid-day or evening (Table 6).

Table 6. Number of Richardson's ground squirrels seen during 5-minute periods at burrow concentrations in mid-morning, mid-afternoon, and early evening during 5 days on the Kevin Rim study area, Montana, 1991 and 1992.[a]

	Morning			Afternoon			Evening		
Year	N	mean	SD	N	mean	SD	N	mean	SD
1991	64	2.1	2.3	35	1.2	1.6	53	1.8	2.5
1992	168	4.7	3.6	98	2.7	3.6	139	3.9	4.6
both	232	3.5	3.3	133	2.0	2.8	192	2.9	3.9

[a] All 5 sites surveyed in 1991 were re-surveyed in 1992 with the addition of 1 site.

There were significantly fewer ($P < 0.1$) ground squirrels seen in 1991 than 1992. Land uses at 1991 sampling sites included mesic grazing, xeric grazing, oilfields, and rangeland along agricultural fields. An additional 1992 site was located in the oilfield.

Human Oilfield Activities

A local maintenance operator worked on a 19-well lease in the oilfield on 23 of 28 days in June 1991. Rain made roads impassible and prevented his field work for 5 days. He spent an average of 48.5 minutes (SD = 46.9) per day in the oilfield driving from well to well, inspecting, and maintaining oil wells and tanks. Extrapolation to the entire developed unit yields 4.3 worker-hours of service per day in 1991 and 5.2 worker-hours of service per day in 1992. Under this level of maintenance the reference unit would have received 0.5 worker-hours of service per day in each year.

One maintenance operator serviced wells daily on top of the southern end of the escarpment and approximately 4 operators worked daily in the remainder of the study area. One or 2 semi-trailer tankers removed stored petroleum from tanks in the area on a weekly basis. Researcher presence was relatively sporadic and unpredictable throughout the study area, varying with road and weather conditions.

DISCUSSION

Nest Substrate Selection

Ferruginous hawks nest on a variety of substrates and often choose the sites most secure from predation (Evans 1983, Myers 1987, MacLaren et al. 1988, Restani 1991, Black 1992, Ramakka and Woyewodzic 1993). Most ferruginous hawk nest structures in the Kevin Rim area were on rock outcrops and cliffs (54%) or on the ground (42%). Greater use of outcrops and cliffs has been reported from 2 areas in Wyoming and New Mexico (MacLaren et al. 1988, Ramakka and Woyewodzic 1993). Use of ground sites and lack of tree nesting in the Kevin Rim area was undoubtedly due to the scarcity of suitably-sized trees, aside from those adjacent to human dwellings. The Kevin Rim may provide more cliff nesting opportunities for ferruginous hawks than most reported areas.

The average number of supernumery nests per occupied ferruginous hawk nest observed in this study (4.8) was considerably larger than that observed in other studies in the northern part of the species' range. Powers (1981) observed that ferruginous hawk pairs with multiple nests in Idaho had an average of 2.6 supernumery nests. Myers (1987) noted that pairs in southwest Montana had an average of 1.3-2.3 alternate nests. Smith and Murphy (1973) believed that ferruginous hawk nests could persist without repair for up to 25 years. The abundance of nesting structures on the Kevin Rim indicates its long-term attractiveness to breeding ferruginous hawks.

Human Influences on Breeding Site Selection

Human activities were rarely centered along powerlines, which provided elevated perches for raptors with the added risk of electrocution. This risk appeared slight for ferruginous hawks in the study area and did not appear to affect nest site selection. Harmata et al. (1991) found that ferruginous hawk nests closer to powerlines in the Kevin Rim area in 1990 had significantly lower productivity than nests farther away. Data from 1991 and 1992 did not confirm that effect.

Prairie falcon eyrie selection was not influenced by powerline distribution. Although prairie falcons may be electrocuted along powerlines (Harmata et al. 1991), their wingspans (91-113 cm) are too small for this to be likely except near transformers (Clark and Wheeler 1987:117). Prairie falcons are obligate scrape nesters. If powerline distributions did affect eyrie selection, the impact was outweighed by the restrictions imposed by the falcons' nesting requirements.

The average minimum distance from occupied ferruginous hawk nests to roads in the Kevin Rim area, 0.5 ± 0.3 km, was similar to those observed in southwest Montana (0.45 ± 0.24 km, Restani 1988), Wyoming (0.44 km, MacLaren 1986), and Washington (0.59 km, Knight and Smith 1982). These studies seem to contradict Ensign (1983), who found that ferruginous hawks nested 4.16 ± 2.71 km from roads in southeastern Montana. Undocumented differences between studies in nest heights, traffic levels, and the juxtaposition of roads and topography may have contributed to the apparent contradiction.

Prairie falcons in the study area nested, on average, 0.4 ± 0.27 km from roads, which was similar to the average of 0.5 km observed near Medicine Bow, Wyoming (MacLaren 1986). Allen (1987:189) observed "5 natural aeries within 300 m of heavily used or gravel roads" but Boyce (1986) found that prairie falcon fledgling productivity in the Mojave Desert was positively correlated with the walking time from eyries to roadheads. Again, undocumented differences in road distributions and traffic levels may preclude direct comparisons between studies.

Topography prevented vehicles from approaching most of the Kevin Rim from below and there was virtually no recreational hiking in the study area. During the breeding season, most vehicles on roads did not stop except at oil wells, and people that did leave their vehicles rarely walked more than 50 m away. Most vehicular travel on top of the cliffs was for oilfield maintenance and largely limited to the southern tip of the escarpment. This may have been why ferruginous hawks and prairie falcons did not avoid nesting close to roads. The attractiveness of the cliff substrate was not greatly reduced by human presence along roads because such presence was slight and limited in scope.

Active oil wells were sites of consistent low-level human presence in the area. In spite of this, ferruginous hawks still chose to nest in the oilfield. The closest active well observable from an occupied nest was 340 m away, which may indicate that nesting pairs chose sites which were visually isolated from human activity. There were many grassland hillsides which appeared identical to occupied nest sites but were not within sight of an active oil well and were not used as nesting sites. Therefore, it did not appear that the presence of active oil wells was reducing the number of ferruginous hawk pairs nesting in the grasslands.

Active oil wells were not in close visual proximity to cliffs suitable for prairie falcon breeding and did not affect prairie falcon eyrie selection. Squires et al. (1993) described a similar situation in northeast Wyoming.

Occupied ferruginous hawk nest density along the escarpment was higher than any in the literature, and the overall density of occupied ferruginous hawk nests in the study area was among the highest reported to date (Appendix B Table 16). The degree of clumping among occupied nests was also greater than previously reported (Appendix B Table 16). This concentration of ferruginous hawk nesting attempts was, like the large number of alternate nests, due to the attractiveness of the cliffs and outcrops as nesting substrates.

Abandonment rates up to 40% have been observed for ferruginous hawks disturbed during egg laying and incubation (White and Thurow 1985). Fyfe and Olendorff (1976) believed that ferruginous hawks were most sensitive to disturbance during territory establishment and egg laying. Ferruginous hawks in this study area were incubating prior to the start of research activities in both years, so nesting pairs that abandoned early due to human activity would have been undetected. Smith and Murphy (1973) found no desertions due to disturbance after eggs hatched, but Schmutz (1984) believed that human habitation and disturbance reduced ferruginous hawk nesting density. The high nesting density of ferruginous hawks in the Kevin Rim area implies that human activities did not reduce the area's attractiveness to nesting ferruginous hawks.

Other than ferruginous hawks and prairie falcons, there were few large raptors observed breeding in the study area so distances between occupied non-conspecific sites were usually between sites of these 2 species. Cody (1974:215) believed that the more ecologically similar 2 individuals are, the less territorial overlap they will allow. If so, intraspecific site distances should be greater than interspecific site distances if competition for breeding sites occurs.

The average minimum distance between occupied nests of different species was less for both ferruginous hawks and prairie falcons than the same distance between 2 conspecific nests, which supports Cody's (1974:215) prediction. Ferruginous hawks and other buteos in Alberta, Oregon, Washington, and southwest Montana showed a similar pattern (Schmutz et al. 1980, Cottrell 1981, Bechard et al. 1990, Restani 1991). The smaller distance from occupied ferruginous hawk nests to unoccupied ferruginous hawk nests, relative to the distance between occupied nests, indicates that most unoccupied nests were probably supernumery structures and not artifacts in unoccupied breeding territories.

Predominant land uses throughout the study area were cattle grazing and petroleum extraction. Lokemoen and Duebbert (1976) found that ferruginous hawk ground nests were always in ungrazed areas but this was not the case in my study area or in that studied by Ramakka and Woyewodzic (1993). These two areas had virtually no ungrazed uncultivated areas (Ramakka and Woyewodzic 1993).

Schmutz (1984) found that breeding ferruginous hawks in Alberta avoided areas that were >50% cultivated, and that areas of 10-30% cultivation supported highest nesting densities of ferruginous hawks (Schmutz 1989). The total amount of cultivation was not measured in the Kevin Rim study area, but I believe it was <40% of the entire area.

Petroleum development in the developed unit has left numerous physical obstacles to cultivation including abandoned pipes, pumps, concrete pump pads, cables, tanks, and evaporation pits. These obstacles, together with uneven and rocky terrain, make it unlikely that much more of the developed unit will be cultivated in the foreseeable future. Similar areas to the south and west of the study area were not developed for petroleum extraction and were cultivated to within 500 m of the escarpments. Those cliffs (7.4 km) supported only 1 nesting pair of ferruginous hawks from 1988-1992 and had only 1/6 the linear density of nest structures (0.41/km) as the adjacent study area (2.15/km) (Dubois 1988, Harmata et al. 1991).

Breeding Site Reuse

Reuse of nests by ferruginous hawks has varied from 11.1% to 100% (Lardy 1985, White and Thurow 1985). Smith and Murphy (1973) believed that nest reuse was related to disturbance and reproductive success at the previous year's nest. Nest reuse observed in the study area was close to that of other ferruginous hawk populations (Howard and Wolfe 1976, Gilmer and Stewart 1983, Wittenhagen 1992). Human activities, therefore, did not appear to prevent reuse of sites or force ferruginous hawks to reuse a limited number of isolated sites. There were fewer prairie falcon breeding sites available and this contributed to a higher site reuse rate.

Reaction to Breeding Site Intrusion

Lack of a significant difference in nest defense (Appendix C), nesting in developed and reference units suggests that there has been no change in ferruginous hawk nest defense in the developed unit relative to the reference unit. Ensign (1983) found the average response distance for nesting ferruginous hawks in southeast Montana to be 170 m, which was much less than the average response distance of 202.8 m observed in this study. In addition, White and Thurow's (1985) 90th percentile (250 m) was <50% of the 95th percentile observed in this study (532 m). Ferruginous hawks in the Kevin Rim area were quicker to respond than ferruginous hawks in other areas.

The observed early response to humans of ferruginous hawks in the study area, relative to other areas, parallels the behavior of disturbed and persecuted corvids noted in other studies. Common ravens (*Corvus corax*) in Washington farmland (Knight 1984) and black-billed magpies (*Pica pica*) in rural Colorado (Kennedy and Knight 1992) harassed by humans had increased flushing distances and less aggressive nest defense than their non-persecuted counterparts. The authors suggested that this was a learned behavioral modification which reduced the adults' chances of being injured or that intruders would find nest sites. Ferruginous hawk reactions to human intrusion in the Kevin Rim area may be the result of past human intrusion at nest sites and enhanced visibility from elevated nest sites. Intensity of ferruginous hawk nest defense was not quantitatively measured in this study, so this theory cannot be entirely supported and the alternative possibility of Kevin Rim hawks being historically unpersecuted and highly agressive cannot be discounted.

White and Thurow (1985) suggested that an alternate factor affecting ferruginous hawk nest defense was poor physiological condition brought about by low prey availability. Harmata et al. (1991:27) found that Richardson's ground squirrels composed 71.4% of the prey taken by ferruginous hawks in the Kevin Rim area. Clark (1970) observed that heavy rains caused Richardson's ground squirrels to cease all above-ground activity, so the wet weather during this study may have decreased ferruginous hawk prey availability. Response distances of ferruginous hawks in the Kevin Rim area were similar to those observed for a congeneric [rough-legged hawks (Buteo regalis)] in Sweden which flew when intruders were 200-400 m from nests during a period of low prey availability (Andersson and Wiklund 1987). Past human activity, low prey availability, and high competitor densities may have all combined to make Kevin Rim ferruginous hawks quicker to react to human intrusion than the birds studied by Ensign (1983) or White and Thurow (1985).

The significant difference between nest defense distances for ferruginous hawks and prairie falcons indicates that ferruginous hawks were quicker to react to intrusion than prairie falcons. The greater height of prairie falcon eyries may have insulated them from intrusion more than ferruginous hawks, but ferruginous hawks reacted sooner than neighboring prairie falcons even when their breeding sites were at the same height. Prairie falcons were more aggressive than ferruginous hawks when they did react, but these differences were not quantified.

Productivity and Population Stability

The lack of statistical significance for actual differences in reproductive success of ferruginous hawks and prairie falcons between the developed and reference units is probably due to the small number of nests involved. Given the population sizes, I cannot place much emphasis on differences in reproductive success between units. The ferruginous hawk reproductive success, number of fledglings per occupied nest, and number of fledglings per successful nest in the Kevin Rim area were lower than median literature values (Appendix B Table 17). The conservative estimated ferruginous hawk nestling and fledgling mortality rate in this study (36.8%) was somewhat lower than the median (49.3%) reported in previous studies (range 0-81.3%) (Lardy 1980, Ensign 1983, Schmutz and Fyfe 1987, Woffinden and Murphy 1989). Human activities in the Kevin Rim area have not increased the pre-dispersal ferruginous hawk mortality rate over that in other areas.

Predation on ferruginous hawk nestlings and fledglings in this area was apparently not unusual for this species (Ensign 1983, Gilmer and Stewart 1983). Escarpment nests were less susceptible to predation but this was nullified by their increased susceptibility to weather-related collapse. Heavy rains and hail had an impact on young ferruginous hawks similar to that seen in North Dakota (Gilmer and Stewart 1983) and have also been a source of nest loss in Alberta (Schmutz and Hungle 1989).

Using Schmutz and Fyfe's (1987) estimates of first year mortality (66%) and annual adult mortality (25%), Woffinden and Murphy (1989) calculated that a ferruginous hawk population must produce an average of 1.5 young/pair/year to maintain stability. According to this criterion, and using additional data from Harmata et al. (1991), the Kevin Rim ferruginous hawk population produced insufficient young to maintain stability in 1990 and 1992.

Shor (1975) estimated the average life span of prairie falcons to be 2.8 years. Prairie falcons in the study area had lower observed productivity than nearly all previously described populations (Appendix B Table 18). Using observed success and mortality rates, observed prairie falcon productivity appears sufficient to maintain stable population levels if at least 60% of subadult and adult prairie falcons attempt to breed. Impressions of ferruginous hawk and prairie falcon population stability based on parameters estimated for other populations are useful only for general comparisons, especially when based on only a few years of study.

Post-fledging Period

Ferruginous hawk post-fledging periods were not remarkably different from those reported in the literature, which indicates that post-fledging movements are quite variable. Konrad and Gilmer (1979) recorded an average postfledging period of 23.2 days, with differences between nest mates <15 days. Ensign (1983:57) noted "that family groups were commonly observed up to 3 weeks after fledging" but Harmata (1981) described the 21 km movement of a fledgling within 8 days after banding.

Prairie falcon post-fledging periods were similar to those observed in American kestrels in Iowa (Varland et al. 1993). Human activities possibly influenced post-fledging movements of ferruginous hawks and prairie falcons in the Kevin Rim area, but the impact was not apparently great. Other possible influences on post-fledging movements are weather, prey availability, and the presence of other raptors.

Foraging Behavior

Richardson's ground squirrels exhibited a bimodal above-ground diurnal activity pattern during June, July, and August, returning to their burrows during the hottest part of the day (Clark 1970, this study). Breeding ferruginous hawks have often been seen to forage most intensively in early morning and late afternoon (Weston 1969, Smith and Murphy 1973, Restani 1988, Harmata et al. 1991) so their foraging efforts appear to be synchronized with ground squirrel availability.

Wakeley (1978a) observed 2 male ferruginous hawks hunting significantly more than expected in pastures and that vegetative density was more important than prey density to foraging ferruginous hawks. Natural elevated perches were rare in the Kevin Rim area, as may be inferred from their rare use by foraging raptors (Appendix E Table 19). Croplands in the study area commonly had fenced borders, and fence posts provided perches that ferruginous hawks could use.

Wakeley (1978b) noted that ferruginous hawks most often used wooden fence posts as foraging perches but one of 2 males in his study did occasionally use telephone poles. Most CRP and fallow lands in the Kevin Rim area were not fenced or were fenced with steel fence posts. Steel posts presented a much smaller perching area (approx. 6 cm^2) than wooden fence posts (approx. 380 cm^2) and were not suitable for ferruginous hawk use. Avoidance of steel fence posts by perching ferruginous hawks was also observed by Powers (1981:46). Oilfields in the study area had lower vegetation densities due to cattle grazing and contained numerous powerpoles, which ferruginous hawks often used as foraging perches.

Foraging ferruginous hawks avoided humans. They avoided primary roads, which had higher levels of human activity, but also avoided tertiary roads, which had the lowest levels of human activity. There were fewer fenceposts and powerpoles along tertiary roads so ferruginous hawks along them had to forage from ground perches or aerially. A ground-perched ferruginous hawk was less conspicuous than if it were perched on an elevated substrate so their use of tertiary roads may have been underestimated. Ferruginous hawks were seen perched on outcrops and the ground more than other species, so visibility bias had little or no impact on the results. A more likely reason for ferruginous hawk avoidance of tertiary roads is that oilfield habitat along secondary roads had more soil disturbance and physical cover for small mammals, so prey densities may have been higher there and relatively low along tertiary roads. Secondary roads in oilfields were favored foraging sites of ferruginous hawks, so human activities in oilfields did not exclude foraging ferruginous hawks, in spite of the hawks' early reactions to humans.

Prairie falcons were common nesters in the area and it seems unusual that they were so seldom seen perched along roadsides. Squires et al. (1993) reported that prairie falcons nesting in northeastern Wyoming foraged in oilfields and perched on powerpoles. The latter behavior was rarely seen in the Kevin Rim area. There were fewer oil wells in this study area (1.07/km^2) than in Squires et al.'s (1993) study area

($1.4/km^2$). Therefore, human activity does not seem to be a likely cause for this contradiction. Since Squires et al.'s (1993) observations were from radio-telemetry sampling, perhaps the falcons' smaller size contributed to the lower observation rate, in spite of observer attempts to avoid such a bias.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

There are 4 possible scenarios concerning human activities and raptors which could exist in the study area. The first possibility is that human land use has negative impacts on local ferruginous hawk and prairie falcon populations. These impacts may limit the number of suitable breeding sites, reduce productivity, and increase mortality. Evidence of these impacts might be: reduced nesting densities (relative to undeveloped areas), lower reproductive rates, lower nest reuse rates, higher nest abandonment rates, foraging behavior which avoids areas of human activity, and high mortality rates from human-related causes. In this scenario, continued presence of nesting ferruginous hawks and prairie falcons would be maintained only by immigration.

The second possible scenario is that local ferruginous hawk and prairie falcon populations exist because impacts of human activities on the populations initially occurred decades ago. Consequently, local populations must have evolved or learned behavioral patterns which allow them to maintain themselves despite human activities. In this case, the breeding density, productivity, and mortality of these populations would not be noticeably different from those in other areas. However, nest site selection, reactions to intrusions, and forage habitat use probably would be different. If birds became more sensitive to human presence, they should nest at undeveloped, visually isolated sites and react more often or sooner to humans. Such ferruginous hawk and prairie falcon populations would likely only currently exist as remnants. If, on the other hand, birds became accustomed to human presence, then their nest site placement and use of foraging habitats should show no relationship to human activities and they should be slower to react to intrusions.

The third possible scenario is one in which human activities negatively affect only a fraction of ferruginous hawk and prairie falcon populations, with non-human factors (i.e. weather, prey availability, nest predators) being of greater importance for most birds and obscuring the effects of human activities. Breeding densities, nest site placement, productivity, forage habitat use, mortality, and behavior would appear normal until the area is more heavily impacted by human activities and more breeding pairs are affected.

The fourth scenario is one in which human activities do not affect the ferruginous hawk and prairie falcon populations. Breeding densities, nest site placement, productivity, forage habitat use, mortality, and behavior would appear similar to those observed in non-impacted areas. Any observed differences would be more easily ascribed to non-human factors than to human activities.

Several generalizations regarding ferruginous hawks and prairie falcons in the Kevin Rim area may be made from evidence gathered in this study. Human activities apparently have not negatively affected breeding site reuse rates, breeding site selection (with the possible exception of some ground nesting ferruginous hawks), breeding densities, post-fledging movements, and pre-dispersal mortality. Although the evidence is not conclusive and there are confounding factors, human activities may be influencing production of young by both species and ferruginous hawk nest defense behavior. Human activities and artifacts do influence foraging ferruginous hawks and may influence foraging prairie falcons. There is insufficient information to address nest abandonment rates.

The evidence does not support the first scenario, that land use is significantly impacting local ferruginous hawk and prairie falcon populations. Compared to other areas, nest densities have not been greatly reduced, foraging ferruginous hawks are not avoiding all areas of human activity, and there is no sign of increased mortality due to humans.

Existing occupied nest densities, nest site selection, and foraging habitat use do not support the second scenario either. Reactions by ferruginous hawks to nest intrusions seem to show behavioral differences relative to other areas, although this may been partially due to low prey availability.

The evidence supports the third scenario, that human activities currently negatively affect only a fraction of local ferruginous hawk and prairie falcon populations. Compared to other areas, ferruginous hawk nesting density is quite high. Overall nest site selection has not been significantly affected but ground nesting ferruginous hawks in the oilfield may be avoiding visual contact with humans. The main factors influencing productivity and mortality are apparently not human-related, and foraging habitat use for ferruginous hawks has not been significantly restricted by human activities. If anything, ferruginous hawk foraging habitat has been improved relative to adjacent areas by the addition of perch sites and the maintenance of relatively natural vegetation.

The evidence does not support the fourth hypothesis, that of no impact. Breeding site reuse, overall nest site selection, and productivity and mortality rates are similar to those seen in other areas, but foraging habitat use appears altered by human activities.

The relatively quick reaction to nest intrusion and low productivity of ferruginous hawks in the Kevin Rim area is somewhat alarming, no matter whether the cause is low prey availability or human activities or both. If ferruginous hawks remain quick to react to humans and nest intrusions increase, the productivity of ferruginous hawks nesting in the area could decline, with oilfield nesters being impacted before cliff nesters. A long-term decline in productivity below current levels could render the population unstable and prevent it from sustaining itself without immigration from other populations.

Periodic monitoring will be necessary to determine raptor population productivity and stability (Olendorff et al. 1989). Such monitoring, if done from the ground, should be done by observers $\geq$300 m away and below the breeding sites, based on the reactions of local raptors. Fyfe and Olendorff (1976) suggest that such activities not be conducted before the late incubation stage, which in the Kevin area begins on approximately 20 May. Annual surveys of local powerlines will help identify specific powerpoles as sources of preventable mortality.

Year-round buffer zones of 800 m and breeding season buffers of 1.6 km have been suggested for ferruginous hawk and prairie falcon nest sites (Call 1979, Suter and Joness 1981). Buffer zones of 500 m appear sufficient to prevent inducing nest defense in most ferruginous hawks and prairie falcons in the Kevin Rim area during post-incubation stages of nesting. Birds which see humans at this range may have increased pulse rates and blood pressure levels (Busch et al. 1978) but they do not accrue the additional metabolic expense of flight, and nest contents are not exposed to weather conditions and predation. Current petroleum extraction activities are not apparently influencing breeding site selection, reproduction, and mortality. Therefore, there is no need to reduce the level of this activity in the area. Seventy-five percent of nesting ferruginous hawks currently choose sites >1.9 km away from active oil wells. Limiting future expansion of the oilfield to land >1.9 km from known nesting sites should minimize the impact on breeding ferruginous hawks and prairie falcons.

Yenser et al. (1992) found that Townsend's ground squirrel (Spermophilus townsendii) populations became unstable and tended to decline as native grassland vegetation in Idaho was replaced by short-lived exotic species (i.e. Bromus tectorum) due to increased fire intensities and overgrazing. Regulation of grazing pressure at moderate levels in the Kevin Rim area would likely maintain Richardson's ground squirrel populations and would maximize prey availability by maintaining relatively open vegetative cover (Call 1979).

Grain cultivation appeared to have only negative impacts on ferruginous hawks and prairie falcons. Since this land use occurs only on private lands, management opportunities are limited. Incentives which favor conversion of grasslands to grain fields (whether direct conversion or conversion preceeded by removal of oilfield artifacts) should be discouraged in the Kevin Rim area. Conservation easement opportunities on private land should be pursued, especially directly along the escarpment and in the reference unit.

Weather is the most limiting factor on ferruginous hawk productivity in the Kevin Rim area. The escarpment will continue to attract nesting ferruginous hawks but if future years are as wet as 1991-1992, the local population may decline. Escarpment nest sites which appear prone to collapse may be stabilized (i.e. reinforcements, removing upper portions of tall nests) after breeding ferruginous hawks leave the area in autumn. If occupied ground nests continue to be washed from hillsides, nearby excavation into hillsides of small (2 m) level divots may prove to be stable nesting platforms for ferruginous hawks. Given the large number of natural, relatively predator-safe nest sites, placement of artificial nest structures should be considered a last resort (Call 1979:60). Artificial nest sites have been shown to boost ferruginous hawk productivity in Idaho (Howard and Hilliard 1980), Alberta (Schmutz et al. 1984), South Dakota (Gaines 1985), Saskatchewan (Houston 1985), and Wyoming (Call and Tigner 1991), but I feel that they would have little affect in the Kevin Rim area at this time due to the apparent attractiveness of natural sites and their expense may be prohibitive given the unpredictability of occupancy by hawks. Any such structures should be placed and maintained in visually isolated locations or $\geq$ 1.9 km from roads or oil wells in grasslands. Planted trees have also been found to provide alternative nesting structures for ferruginous hawks (Olendorff and Stoddart 1974), but chances of successful tree growth and survival are low in most of the Kevin Rim area. In addition, planted trees would have to be protected from livestock impacts (Olendorff and Stoddart 1974) and would not be available for use by ferruginous hawks for many years. Planting trees is, therefore, not likely to benefit breeding ferruginous hawks.

A primary factor in raptor management in the Kevin Rim area will be local public opinion. The prevailing local attitude seems neutral but a number of local residents are concerned over potential negative economic impacts of raptor management activities. Given local knowledge of many nest sites, relatively easy access to nest vicinities, and the large number of raptors perching along roadsides, negative actions by a few individuals could greatly impact local raptor populations. Conversely, some local cattle ranchers wanted raptor numbers to increase as a means of controlling small mammal numbers. The BLM has already taken steps to address public attitudes and beliefs and reduce human presence near breeding concentrations along the Kevin Rim (i.e. placing cautionary signs). The positive interest of some local residents may enhance such management measures and should be encouraged by management agencies.

LITERATURE CITED

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Allen, G.T. 1987. Prairie falcon aerie site characteristics and aerie use in North Dakota. Condor 89:187-190.

Andersen, D.E. 1990. Nest-defense behavior of red-tailed hawks. Condor 92:991-997.

Andersson, M., C.G. Wiklund, and H. Rundgren. 1980. Parental defence of offspring: a model and an example. Anim. Behav. 28:536-542.

Andersson, S., and C.G. Wiklund. 1987. Sex-role partitioning during offspring protection in the rough-legged buzzard _Buteo lagopus_. Ibis 129:103-107.

Bechard, M.J. 1982. Effect of vegetative cover on foraging site selection by Swainson's hawk. Condor 84:153-159.

____________, R.L. Knight, D.G. Smith, and R.E. Fitzner. 1990. Nest sites and habitats of sympatric hawks (_Buteo_ ssp.) in Washington. J. Field Ornith., 61:159-170.

Becker, D.M. and Ball, I.J. 1983. Prairie falcon (_Falco mexicanus_). Pages 138-153 _in_ J.S. Armbruster (ed). Impacts of coal surface mining on 25 migratory bird species of high federal interest. U.S. Dept. Interior, Fish and Wildl. Serv., Fort Collins, CO.

Berger, D.D., and H.C. Mueller. 1959. The bal-chatri: a trap for the birds of prey. Bird-Banding 30:18-26.

Bierman, G.C., and R.J. Robertson. 1981. An increase in parental investment during the breeding season. Anim. Behav. 29:487-489.

Black, A. 1992. Ferruginous hawk reproduction and habitat survey: challenge cost share report to U.S. Dept. Interior, Bur. Land. Manage., Malta, MT. 16pp.

Blair, C.L., and F. Schitoskey, Jr. 1982. Breeding biology and diet of the ferruginous hawk in South Dakota. Wilson Bull. 94:46-54.

Boyce, D.A., Jr. 1986. Factors affecting prairie falcon fledgling productivity in the Mojave Desert, California. Pages 237-247 _in_ R.L. Glinski, B.G. Pendleton, M.B. Moss, M.N. LeFranc, Jr., B.A. Millsap, and S.W. Hoffman (editors). Southwest Raptor Manage. Symp. and Work. National Wildl. Fed. Sci. and Tech. Series 11.

Bureau of Census. 1990. Number of inhabitants. Census of the pop. 1:A-28. U.S. Dept. Comm., Wash., D.C.

Busch, D.E., W.A. deGraw, and N.C. Clampitt. 1978. Effects of handling-disturbance stress on heart rate in the ferruginous hawk (Buteo regalis). Raptor Res. 12:122-125.

Call, M.W. 1979. Habitat management guides for birds of prey. U.S. Dept. Inter., Bur. Land Manage., Denver, CO. Tech. Note TN-338 70pp.

__________, and J.R. Tigner. 1991. Artificial nesting structures for ferruginous hawks (Buteo regalis) in Wyoming. Paper presented at Raptor Res. Found. 1991 annual meeting. Nov. 6-10, 1991, Tulsa, OK.

Clark,P.J., and F.C. Evans. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35:445-453.

Clark, R.J., and J.G. Ward. 1974. Interspecific competition in two species of open country raptors Circus cyaneus and Asio flammeus. Proc. Penn. Acad. Sci. 48:79-87.

Clark, T.W. 1970. Richardson's ground squirrels (Spermophilus richardsonii) in the Laramie Basin, Wyoming. Great Basin Nat. 30:55-70.

Clark, W.S., and B.K. Wheeler. 1987. A field guide to hawks of North America. Peterson Field Guide Ser. 35, Houghton Mifflin Co., Boston, MA. 163pp.

Cody, M.L. 1974. Competition and the structure of bird communities. Princeton Univ. Press, Princeton, NJ. 318pp.

Cottrell, M.J. 1981. Resource partitioning and reproductive success of three species of hawks (Buteo ssp.) in an Oregon prairie. M.S. thesis, Oregon State Univ., Corvallis. 72pp.

Craighead, J.J., and F.C. Craighead. 1969. Hawks, owls and wildlife. Dover Publ., Inc. New York, NY. 443pp.

Craighead, F.G., Jr., and D.P. Mindell. 1981. Nesting raptors in western Wyoming. J. Wildl. Manage. 45:865-872.

Daniel, W.W. 1990. Applied non-parametric statistics. PWS-Kent Publishing Co., Boston, MA. 633pp.

DeVelice, R.L. 1991. Plant communities of the Kevin Rim, Toole County, Montana: Preliminary survey results. Montana Nat. Her. Prog., Helena. 14pp.

Dubois, K.L. 1988. Kevin Rim/Sweetgrass Hills raptor survey, final report. U.S. Dept. Interior, Bur. Land Manage., Great Falls, MT. 6pp.

Eakle, W.L. 1984. Observations of nesting prairie falcons in the Los Padres National Forest. Raptor Res. 18:31-33.

Edwards, B. 1973. A nesting study of a small population of prairie falcons in southern Alberta. Can. Field Nat. 87:322-324.

Enderson, J.H. 1964. A study of the prairie falcon in the central Rocky Mountain region. Auk 81:332-352.

Ensign, J.T. 1983. Nest site selection, productivity, and food habits of ferruginous hawks in southeastern Montana. M.S. thesis, Montana State Univ., Bozeman. 85pp.

Evans, D.L. 1983. Ferruginous hawk (Buteo regalis). Pages 109-123 in J.S. Armbruster (ed). Impacts of coal surface mining on 25 migratory bird species of high federal interest. U.S. Dept. Interior, Fish and Wildlife Service, Fort Collins, CO.

Fitzner, R.E., D. Berg, L.L. Boyd, and C.A. Rieck. 1977. Nesting of ferruginous hawks (Buteo regalis) in Washington 1974-1975. Condor 79:245-249.

Flath, D.L. 1984. Species of special interest or concern, mammals, birds, reptiles, amphibians, fishes. Montana Dept. Fish, Wildl. and Parks, Wildl. Div., Helena. 76pp.

Fraser, J.D., L.D. Frenzel, and J.E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. J. Wildl. Manage. 49:585-592.

Fyfe, R.W., and R.R. Olendorff. 1976. Minimizing dangers of nesting studies to raptors and other sensitive species. Can. Wildl. Ser. Occas. Paper 23. 17pp.

Gaines, R.C. 1985. Nest site selection, habitat utilization, and breeding biology of the ferruginous hawk in central North Dakota. M.S. thesis, North Dakota State Univ., Fargo. 32pp.

Gilmer, D.S., and R.E. Stewart. 1983. Ferruginous hawk populations and habitat use in North Dakota. J. Wildl. Manage. 47:146-157.

Gossett, D.N., and M.J. Bechard. 1992. Morphological differences of ferruginous hawks (Buteo regalis) east and west of the Rocky Mountains. Paper presented at the 1992 Raptor Res. Found. annual meetings, 11-15 November, Bellevue, WA.

Haak, B.A. 1983. Foraging ecology of prairie falcons in northern California. M.S. thesis, Oregon State Univ., Corvallis. 64pp.

Hamerstrom, F. 1986. Harrier, hawk of the marshes. Smithsonian Inst. Press, Wash., D.C. 171pp.

Harmata, A.R. 1981. Recoveries of ferruginous hawks banded in Colorado. N. Amer. Bird Bander 6:144-147.

__________, M.R. Restani, B. Hatcher, A. House, and S. Grantham. 1991. Impacts of oil and gas development on raptors associated with the Kevin Rim, Montana. Rep. to the U.S. Dept. Interior, Bur. Land Manage., Great Falls, MT. 80pp.

Hollin, J.T., and D.H. Schilling. 1981. Late Wisconsin - Weichselian mountain glaciers and small ice caps. Pages 179-206 in G.H. Denton and T.J. Hughes, ed. The last great ice sheets. John Wiley and Sons, New York.

Houston, C.S. 1985. Ferruginous hawk nest platforms - progress report. Blue Jay 43:243-246.

Howard, R.P., and M.L. Wolfe. 1976. Range improvement practices and ferruginous hawks. J. Range Manage. 29:33-37.

__________, and M. Hilliard. 1980. Artificial nest structures and grassland raptors. Raptor Res. 14:41-45.

Johnsgard, P.A. 1990. Hawks, eagles, and falcons of North America: biology and natural history. Smithsonian Inst. Press, Wash., D.C. 403pp.

Kennedy, S.P., and R.L. Knight. 1992. Flight distances of black-billed magpies in different regimes of human density and persecution. Condor 94:545-547.

Knight, R.L. 1984. Responses of nesting ravens to people in areas of different human densities. Condor 86:345-346.

__________, and D.G. Smith. 1982. Summer raptor populations of a Washington coulee. Northwest Sci. 56:303-309.

__________, and S.A. Temple. 1986a. Nest defence in the American goldfinch. Anim. Behav. 34:887-897.

__________, and __________. 1986b. Methodological problems in studies of avian nest defence. Anim. Behav. 34:561-566.

Konrad, P.M., and D.S. Gilmer. 1986. Post fledging behavior of ferruginous hawks in North Dakota. Raptor Res. 20:35-39.

Lardy, M.E. 1980. Raptor inventory and ferruginous hawk breeding biology in southeastern Oregon. M.S. thesis, Univ. Idaho, Moscow. 52pp.

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

MacLaren, P.A. 1986. Resource partitioning in an assemblage of breeding raptors from southeastern Wyoming. M.S. thesis, Univ. Wyoming, Laramie. 64pp.

______________, S.H. Anderson, and D.E. Runde. 1988. Food habits and nest characteristics of breeding raptors in southwestern Wyoming. Great Basin Nat. 48:548-553.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

Meredith, R.L. 1969. Methods, ancient, medieval, and modern for the capture of falcons and other birds of prey. Pages 433-439 in C.A. Wood and F.M. Fyfe, eds. The art of falconry. Stanford University Press, Stanford, CA.

Montgomerie, R.D., and P.J. Weatherhead. 1988. Risks and rewards of nest defence by parent birds. Q. Rev. Biol. 63:167-187.

Moritsch, M.Q. 1983. Photographic guide for aging nestling prairie falcons. Snake River Birds of Prey Proj., U.S. Dept. Interior, Bur. Land Manage., Boise, ID. 11pp.

____________. 1985. Photographic guide for aging nestling ferruginous hawks. Snake River Birds of Prey Proj. Bur. Land Manage., Boise, ID. 19pp.

Myers, L.H. 1987. Nesting ecology of ferruginous hawks in southwest Montana. Paper presented at Montana Nongame Symp., Feb. 11, 1987, Kalispell. 14pp.

National Audubon Society. 1992. Ferruginous hawk hits hard times. Amer. Birds 46:12-13.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-555.

Ogden, V.T., and M.G. Hornocker. 1977. Nesting density and success of prairie falcons in southwestern Idaho. J. Wildl. Manage. 41:1-11.

Olendorff, R.R. 1973. Ecology of the nesting birds of prey in northeastern Colorado. U.S.I.B.P. Grassland Biome Tech. Rep. 211. 233pp.

______________, C.C. Bibles, M.T. Dean, J.R. Haugh, and M.N. Kochert. 1989. Raptor habitat management under the U.S. Bureau of Land Management multiple-use mandate. Raptor Res. Rep. No. 8. 80pp.

_____________, and J.W. Stoddart, Jr. 1974. The potential for management of raptor populations in western grasslands. Pages 47-88 in F.N. Hamerstrom, Jr., B.E. Harrell, and R.R. Olendorff, eds. Management of raptors. Raptor Res. Rep. No. 2.

Paulson, D.R. 1973. Predator polymorphism and apostatic selection. Evol. 27:269-277.

Postupalsky, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. Pages 21-31 in F.N. Hamerstrom Jr., B.E. Harrell, and R.R. Olendorff, eds. Management of raptors. Proc. Conf. Raptor Cons. Tech. Raptor Res. Rep. 2

Perry, E.S. 1953. Oil and gas in Montana. Montana Bur. of Mines and Geol. Mem. 35. Montana School of Mines, Butte.

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

Platt, S.W. 1981. Population dynamics of the prairie falcon in northeastern Colorado. Pages 1-48 in S.W. Platt. Prairie falcon: aspects of population dynamics, individual vocal identification, marking, and sexual maturity. Ph. D. diss., Brigham Young Univ., Provo, Utah.

Powers, L.R. 1981. Nesting behavior of the ferruginous hawk (Buteo regalis). Ph. D. diss., Idaho State Univ., Boise. 312pp.

Prairie Homemaker's Home Extension Club and Jayhawkers Ridge Home Extension Club. 1976. Echoes from the past: history of north Toole County. Shelby Promoter, Shelby, MT. 668pp.

Ramakka, J.M., and R.T. Woyewodzic. 1993. Nesting ecology of ferruginous hawks in northwestern New Mexico. J. Raptor Res. 27:97-101.

Restani, M. 1989. Resource partitioning among three species of hawks in the Centennial Valley, Montana. M.S. thesis, Montana State University, Bozeman. 86pp.

___________, 1991. Resource partitioning among three Buteo species in the Centennial Valley, Montana. Condor 93:1007-1010.

Schmutz, J.K. 1977. Relationships between three species of the genus Buteo (Aves) coexisting in the prairie-parkland ecotone of southeast Alberta. M.S. thesis, Univ. Alberta, Edmonton. 126pp.

___________. 1984. Ferruginous and Swainson's hawk abundance and distribution in relation to land use in southeastern Alberta. J. Wildl. Manage. 48:1180-1187.

___________. 1989. Hawk occupancy of disturbed grasslands in relation to models of habitat selection. Condor 91:362-371.

___________, and R.W. Fyfe. 1987. Migration and mortality of Alberta ferruginous hawks. Condor 89:169-174.

___________, and D.J. Hungle. 1989. Populations of ferruginous hawks and Swainson's hawks increase in synchrony with ground squirrels. Can. J. Zool. 67:2596-2601.

___________, S.M. Schmutz, and D.A. Boag. 1980. Coexistence of three species of hawks (Buteo ssp.) in the prairie-parkland ecotone. Can. J. Zool. 50:1075-1089.

Schmutz, S.M., and J.K. Schmutz. 1981. Inheritance of color phases of ferruginous hawks. Condor 83:187-189.

Shapiro, S.S., and M.B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591-611.

Shor, W. 1975. Survival rate of wild adult prairie falcons deduced from band recovery data. Raptor Res. 9:46-50.

Smith, D.G., and J.R. Murphy. 1973 Breeding biology of raptors in the eastern Great Basin of Utah. Sci. Bull. Ser. 18:1-76, Brigham Young University, Provo, Utah.

__________, and __________. 1978. Biology of the ferruginous hawk in central Utah. Sociobiol. 3:79-95.

Snyder, N.F.R., and J.W. Wiley. 1976. Sexual size dimorphism in hawks and owls of North America. Ornithol. Monogr. No. 20. American Ornithol. Union, Wash., D.C. 96pp.

Sproat, T.M., and G. Ritchison. 1993. The nest defense of eastern screech-owls: effects of nest stage, sex, nest type and predator location. Condor 95:288-296.

Squires, J.R., S.H. Anderson, and R. Oakleaf. 1993. Home range size and habitat-use patterns of nesting prairie falcons near oil developments in northeast Wyoming. J. Field Ornith. 64:1-10.

Steenhof, K., and M.N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. J. Wildl. Manage. 46:885-893.

___________, and ___________. 1985. Dietary shifts of sympatric buteos during a prey decline. Oecologia 66:6-16.

Suter, G.W., and J.L. Joness. 1981. Criteria for golden eagle, ferruginous hawk and prairie falcon nest site protection. Raptor Res. 15:12-18.

Tate, J., Jr. 1986. The blue list for 1986. Amer. Birds 40:227-236.

Thurow, T.L., and C.M. White. 1983. Nest site relationships between the ferruginous hawk and Swainson's hawk. J. Field. Ornith. 54:401-406.

U.S. Dept. Commerce. 1973. Climates of the United States. Govt. Press, Wash., D.C. 113pp.

__________________. 1991. Climatological data annual summary for Montana. Natl. Env. Sat., Data and Inf. Serv., Natl. Climatic Data Center, Asheville, NC.

__________________. 1992. Climatological data annual summary for Montana. Natl. Env. Sat., Data and Inf. Serv., Natl. Climatic Data Center, Asheville, NC.

Varland, D.E., E.E. Klaas, and T.M. Loughlin. 1993. Use of habitat and perches, causes of mortality and time until dispersal in post-fledging American kestrels. J. Field Ornith. 64:169-178.

Wakeley, J.S. 1978a. Factors affecting the use of hunting sites by ferruginous hawks. Condor 80:316-326.

____________. 1978b. Hunting methods and factors affecting their use by ferruginous hawks. Condor 80:327-333.

Wallin, K. 1986. Defence as parental care in tawny owls (Strix aluco). Behav. 102:213-230.

Warkentin, I.G., and P.C. James. 1988. Trends in winter distribution and abundance of ferruginous hawks. J. Field Ornith. 59:209-214.

Weatherhead, P.J. 1979. Do savannah sparrows commit the Concorde fallacy? Behav. Ecol. Sociobiol. 5:373-381.

Westneat, D.F. 1989. Intensity of nest defense in indigo buntings increases with stage and not number of visits. Auk 106:747-749.

Weston, J.B. 1969. Nesting ecology of the ferruginous hawk (Buteo regalis). Pages 25-36 in J.R. Murphy, ed. Nesting ecology of raptorial birds in central Utah. Sci. Bull. Ser. 10, Brigham Young Univ., Provo, Utah.

White, C.M., and T.L. Thurow. 1985 Reproduction of ferruginous hawks exposed to controlled disturbance. Condor 87:14-22.

Wittenhagen, K.W. 1992. Final report on the ferruginous hawk in southeastern Montana. U.S. Dept. Interior, Bur. Land Manage., Miles City, MT. 31pp.

Woffinden, N.D., and J.R. Murphy. 1989. Decline of a ferruginous hawk population: a 20-year summary. J. Wildl. Manage. 53:1127-1132.

Yensen, E., D.L. Quinney, K. Johnson, K. Timmerman, and K. Steenhof. 1992. Fire, vegetation changes, and population fluctuations of Townsend's ground squirrels (Spermophilus townsendii). Amer. Midl. Nat. 128:299-312.

APPENDICES

APPENDIX A

MAMMALIAN AND AVIAN SPECIES OF THE KEVIN RIM AREA

Table 7. Mammalian species observed on the Kevin Rim study area, Montana, 1991 and 1992.

Common name	Scientific name
Deer mouse	Peromyscus maniculatus
Desert cottontail rabbit	Sylvilagus audubonii
White-tailed jackrabbit	Lepus townsendii
Least chipmunk	Eutamias minimus
Yellow-bellied marmot	Marmota flaviventris
Richardson's ground squirrel	Spermophilus richardsonii
Northern pocket gopher	Thomomys talpoides
Bushytail woodrat	Neotoma cinerea
Porcupine	Erethizon dorsatum
Coyote	Canis latrans
Red fox	Vulpes vulpes
Long-tailed weasel	Mustela frenata
Badger	Taxidea taxus
Striped skunk	Mephitis mephitis
Elk	Cervus elaphus
Mule deer	Odocoileus hemionus
Pronghorn antelope	Antilocapra americana

Table 8. Avian species observed on the Kevin Rim study area, Montana, 1991 and 1992.

Common name	Scientific name
American white pelican	Pelecanus erythrorhynchos
Great blue heron	Ardea herodias
*Canada goose	Branta canadensis
*Mallard	Anas platyrhynchos
Bufflehead	Bucephala albeola
Ruddy duck	Oxyura jamaicensis
*Northern harrier	Circus cyaneus
*Swainson's hawk	Buteo swainsoni
*Red-tailed hawk	Buteo jamaicensis
*Ferruginous hawk	Buteo regalis
Rough-legged hawk	Buteo lagopus
*Golden eagle	Aquila chrysaetos
*American kestrel	Falco sparverius
*Prairie falcon	Falco mexicanus
*Gray partridge	Perdix perdix
*Ring-necked pheasant	Phasianus colchicus
*Sharp-tailed grouse	Tympanuchus phasianellus
*Sora	Porzana carolina
*Killdeer	Charadrius vociferus
*American avocet	Recurvirostra americana
*Willet	Catoptrophorus semipalmatus
*Long-billed curlew	Numenius americanus

Table 8. Continued.

Common name	Scientific name
Ring-billed gull	Larus delawarensis
California gull	Larus californicus
*Rock dove	Columba livia
*Mourning dove	Zenaida macroura
*Great horned owl	Bubo virginianus
*Burrowing owl	Athene cunicularia
*Common nighthawk	Chordeiles minor
Lewis' woodpecker	Melanerpes lewis
*Say's phoebe	Sayornis saya
*Western kingbird	Tyrannus verticalis
Eastern kingbird	Tyrannus tyrannus
*Horned lark	Eremophila alpestris
*Tree swallow	Tachycineta bicolor
*Northern rough-winged swallow	Stelgidopteryx serripennis
*Cliff swallow	Hirundo pyrrhonota
*Barn swallow	Hirundo rustica
*Black-billed magpie	Pica pica
*American crow	Corvus brachyrhynchos
*Rock wren	Salpinctes obsoletus
Mountain bluebird	Sialia currucoides
*American robin	Turdus migratorius
Cedar waxwing	Bombycilla cedrorum
*European starling	Sturnus vulgaris
*Western meadowlark	Sturnella neglecta
*Red-winged blackbird	Agelaius phoeniceus
*Yellow-headed blackbird	Xanthocephalus xanthocephalus
*Common grackle	Quiscalus quiscula
*Brown-headed cowbird	Molothrus ater
American goldfinch	Carduelis tristis
*House sparrow	Passer domesticus

* species known or suspected to breed on the study area, 1991 and 1992

APPENDIX B

STATISTICAL TABLES AND COMPARISONS

Table 9. Road densities (km/km^2) in the three units and the entire Kevin Rim study area, Montana, 1991 and 1992.

region	1° roads	2° roads	3° roads	all roads
reference	0.02	0.00	1.01	1.03
extension	0.00	0.11	1.06	1.17
developed	0.07	0.16	1.49	1.72
entire area	0.04	0.11	1.30	1.45

Table 10. Ferruginous hawk (FH) and prairie falcon (PF) nest locations, substrates, and reproductive history on the Kevin Rim study area, Montana, 1991 and 1992.

Species	UTME	UTMN	Substrate	Occupancy[a]	Success[b]
FH	430.08	5412.88	ground	neither	NA
FH	425.30	5413.90	cliff	neither	NA
FH	424.70	5412.60	ground	neither	NA
FH	430.65	5412.94	ground	neither	NA
FH	427.27	5410.15	outcrop	neither	NA
FH	429.50	5412.55	ground	neither	NA
FH	430.67	5412.69	ground	neither	NA
FH	430.42	5412.08	ground	neither	NA
FH	424.69	5412.65	cliff	neither	NA
FH	429.25	5411.75	ground	neither	NA
FH	425.76	5409.00	cliff	neither	NA
FH	430.08	5412.20	ground	neither	NA
FH	429.52	5412.53	ground	neither	NA
FH	424.88	5413.50	cliff	neither	NA
FH	426.55	5409.25	outcrop	neither	NA
FH	430.06	5413.00	outcrop	neither	NA
FH	426.75	5408.90	outcrop	neither	NA
FH	425.46	5413.80	cliff	neither	NA
FH	428.62	5412.04	ground	neither	NA
FH	430.06	5413.00	ground	neither	NA
FH	430.35	5412.73	ground	neither	NA
FH	428.42	5412.04	ground	neither	NA
FH	428.10	5412.10	ground	neither	NA
FH	430.42	5412.60	ground	neither	NA
FH	425.80	5409.00	cliff	neither	NA
FH	427.42	5410.17	outcrop	neither	NA
FH	426.85	5409.96	outcrop	neither	NA
FH	425.30	5411.80	cliff	neither	NA
FH	429.25	5411.90	ground	neither	NA
FH	426.30	5408.85	cliff	neither	NA
FH	425.06	5411.15	cliff	neither	NA
FH	426.65	5409.67	outcrop	neither	NA
FH	422.30	5404.69	outcrop	neither	NA
FH	430.33	5412.70	ground	neither	NA

Table 10. Continued

Species	UTMN	UTME	Substrate	Occupancy[a]	Success[b]
FH	426.83	5408.94	outcrop	neither	NA
FH	429.80	5412.08	ground	neither	NA
FH	428.85	5412.45	ground	neither	NA
FH	430.40	5412.38	ground	neither	NA
FH	424.70	5412.70	ground	neither	NA
FH	425.79	5409.69	ground	neither	NA
FH	426.00	5407.90	outcrop	neither	NA
FH	426.50	5408.30	outcrop	neither	NA
FH	425.60	5407.70	cliff	neither	NA
FH	426.31	5407.65	ground	neither	NA
FH	422.77	5403.38	ground	neither	NA
FH	426.45	5407.70	ground	neither	NA
FH	421.75	5403.92	outcrop	neither	NA
FH	426.08	5407.78	outcrop	neither	NA
FH	426.00	5407.88	outcrop	neither	NA
FH	422.35	5404.58	outcrop	neither	NA
FH	425.50	5407.70	cliff	neither	NA
FH	426.10	5407.30	ground	neither	NA
FH	425.06	5405.54	ground	neither	NA
FH	425.23	5406.12	ground	neither	NA
FH	426.00	5407.28	ground	neither	NA
FH	422.96	5404.38	outcrop	neither	NA
FH	421.58	5403.60	cliff	neither	NA
FH	422.60	5403.25	cliff	neither	NA
FH	424.55	5405.00	cliff	neither	NA
FH	422.15	5403.40	cliff	neither	NA
FH	421.85	5403.55	cliff	neither	NA
FH	422.80	5403.30	ground	neither	NA
FH	426.70	5408.20	outcrop	neither	NA
FH	426.30	5407.85	outcrop	neither	NA
FH	423.25	5403.50	outcrop	neither	NA
FH	421.40	5403.39	ground	neither	NA
FH	422.40	5403.73	outcrop	neither	NA
FH	421.75	5403.60	cliff	neither	NA
FH	422.73	5404.42	outcrop	neither	NA
FH	421.65	5403.60	cliff	neither	NA
FH	426.43	5408.05	outcrop	neither	NA
FH	426.65	5405.92	ground	neither	NA
FH	424.15	5404.81	cliff	1991	neither
FH	425.67	5410.81	outcrop	1991	neither
FH	426.37	5407.85	ground	1991	neither
FH	428.73	5412.03	outcrop	1992	neither
FH	425.58	5410.70	ground	1992	neither
FH	425.08	5413.70	cliff	1992	neither
FH	431.70	5410.10	structure	1992	neither
FH	425.23	5406.12	ground	both	neither
FH	427.19	5410.12	outcrop	1991	1991
FH	422.46	5404.69	outcrop	1991	1991

Table 10. Continued

Species	UTMN	UTME	Substrate	Occupancy[a]	Success[b]
FH	430.50	5413.08	ground	1991	1991
FH	424.88	5413.42	ground	1991	1991
FH	430.50	5412.71	ground	1991	1991
FH	426.46	5409.38	outcrop	1992	1992
FH	425.25	5411.45	outcrop	1992	1992
FH	430.42	5412.60	ground	1992	1992
FH	426.38	5407.85	ground	1992	1992
FH	426.69	5408.27	outcrop	1992	1992
FH	423.15	5405.00	outcrop	1992	1992
FH	431.35	5412.65	ground	1992	1992
FH	425.15	5412.00	cliff	both	1991
FH	424.58	5405.04	cliff	both	1991
FH	422.13	5403.27	cliff	both	1991
FH	425.70	5404.70	ground	both	1992
FH	426.88	5405.91	ground	both	1992
FH	423.46	5403.46	cliff	both	1992
PF	423.15	5403.38	cliff	both	1991, 1992
PF	425.50	5413.90	cliff	neither	NA
PF	425.54	5413.85	cliff	both	1991, 1992
PF	424.73	5412.77	cliff	both	1991, 1992
PF	427.00	5409.70	cliff	both	1991, 1992
PF	423.54	5403.54	cliff	both	1992
PF	426.70	5408.25	cliff	1992	1992
PF	423.67	5404.08	cliff	neither	NA
PF	423.95	5404.40	cliff	1992	1992
PF	424.31	5404.92	cliff	both	1991
PF	424.62	5406.15	outcrop	neither	NA
PF	426.31	5407.85	outcrop	both	1992
PF	422.19	5404.63	outcrop	neither	NA
PF	421.92	5403.54	cliff	both	neither
PF	424.77	5407.27	cliff	both	1992
PF	426.60	5408.30	cliff	neither	neither
PF	425.40	5407.70	cliff	neither	neither
PF	424.00	5404.42	cliff	both	1991, 1992
PF	422.54	5403.27	cliff	both	1991, 1992
PF	422.27	5403.19	cliff	both	1991, 1992

[a] The year(s) (1991, 1992) in which the nest site was occupied by raptors. 'Neither' indicates an unoccupied site.

[b] The year(s) (1991, 1992) in which the nest site produced fledglings. 'NA' indicates that the site was unoccupied.

Table 11. Distance (km) from unoccupied and occupied ferruginous hawk and prairie falcon breeding sites to the nearest sources of human activity and occupied raptor sites on the Kevin Rim study area, Montana, 1991 and 1992.

		Distance			Percentile		
Nest Status	Activity	mean	SD	median	75th	90th	95th
Ferruginous Hawk							
Occupied (N=25)	Powerline	2.4	1.9	2.3	3.7	5.0	6.5
	Road	0.5	0.3	0.5	0.8	1.0	1.1
	Well	1.4	1.1	1.2	1.7	3.5	3.6
	Other species	0.9	1.1	0.7	0.9	3.1	4.5
	Same species	1.0	0.5	1.1	1.4	1.7	1.8
Unoccupied (N=73)	Powerline	2.4	1.9	2.0	3.6	5.2	5.8
	Road	0.5	0.3	0.4	0.7	0.8	1.1
	Well	0.6	1.1	1.1	2.0	3.6	3.6
	Other species	0.6	0.7	0.5	0.7	1.2	3.0
	Same species	0.4	0.3	0.5	0.6	0.8	0.9
Prairie Falcon[a]							
Occupied (N=25)	Powerline	1.6	2.0	0.9	1.3	5.9	6.8
	Road	0.4	0.3	0.3	0.4	0.8	1.2
	Well	0.8	0.4	0.9	1.1	1.2	1.3
	Other species	0.3	0.2	0.3	0.4	0.5	0.7
	Same species	0.6	0.5	0.3	1.2	1.5	1.5
Unoccupied (N=5)	Powerline	2.1	2.4	1.2			
	Road	0.4	0.2	0.5			
	Well	1.0	0.4	1.2			
	Other species	0.4	0.3	0.3			
	Same species	0.7	0.3	0.6			

[a] The unoccupied eyrie sample size was too small to present meaningful percentiles.

Table 12. Distances (m) at which ferruginous hawks reacted in response to a human intruder near their nests in the reference and developed units of the Kevin Rim study area, Montana, 1991 and 1992.

	Distance				Percentile		
Response	N	mean	SD	median	75^{th}	90^{th}	95^{th}
Reference unit							
First reaction	49	214.8	166.8	152	285	531	551
Flushed	47	212.4	167.6	152	300	530	570
Called	44	176.4	126.8	145	230	400	450
Developed unit							
First reaction	42	194.5	155.6	180	280	438	520
Flushed	40	191.5	143.7	180	265	355	480
Called	35	196.9	150.4	180	300	380	510

Table 13. Distances (m) at which prairie falcons reacted in response to a human intruder near their eyries in the reference and developed units of the Kevin Rim study area, Montana, 1991 and 1992.

	Distance				Percentile		
Response	N	mean	SD	median	75^{th}	90^{th}	95^{th}
Reference unit							
First reaction	24	88.0	61.6	77.5	85	190	230
Flushed	23	80.5	52.1	70.0	85	150	190
Called	18	94.3	69.2	67.5	120	230	266
Developed unit							
First reaction	63	98.7	68.8	80.0	140	200	270
Flushed	63	78.4	60.9	60.0	100	150	200
Called	56	98.1	73.9	80.0	140	210	270

Table 14. Grouped confidence intervals (90%) for observed (O) and expected use[a] of foraging perches by ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks on the Kevin Rim study area, Montana, 1991 and 1992.[b]

Species	Foraging perch (% of use)[c]			
	Flying	Outcrops and ground	Fenceposts	Oilpumps and powerpoles
Ferruginous hawk (N=116)	7<O<28	25<O<53	0<O<13	23<O<51
Swainson's hawk (N=58)	1<O<17	4<O<24	29<O<57	21<O<48
Northern harrier (N=55)	67<O<90	0<O<15	5<O<24	0
Red-tailed hawk (N=21)	0<O<10	1<O<16	24<O<51	36<O<64
Expected	27	17	25	37

[a] The "expected" use was based on observed use by the four raptors.
[b] Underlined confidence intervals indicate a significant departure from expected use.
[c] Categories were combined where necessary to meet the requirements of Neu et al. (1974).

Table 15. Grouped confidence intervals (90%) for observed (O) and expected use of roads and roadside habitats by ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks on the Kevin Rim study area, Montana, 1991 and 1992.[a]

	Road type (% of use)			Habitat type (% of use)			
Species	Primary	Secondary	Tertiary	Range	Fallow	Crop	Oil
Ferruginous hawk (N=116)	8<O<22	75<O<90	0<O<6	56<O<66	1<O<4	3<O<9	26<O<36
Swainson's hawk (N=58)	20<O<46	30<O<60	10<O<34	40<O<56	3<O<11	24<O<38	8<O<20
Northern harrier (N=55)	12<O<36	44<O<72	7<O<29	30<O<46	30<O<46	14<O<28	1<O<7
Red-tailed hawk (N=21)	34<O<80	20<O<66		40<O<67	4<O<22		21<O<46
Available	27	55	18	64	7	8	21

[a] Underlined confidence intervals indicate a significant departure from expected use.

Table 16. Density and distribution of occupied ferruginous hawk nests reported in the literature and observed on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Source	Location	Area (km^2) per occupied nest	R-value[b]	Average distance (km) to nearest conspecific nest
Black 1992	Montana	52		
Blair and Schitoskey 1982	North Dakota	292-412		5-7
Cottrell 1981	Oregon		1.14	
Ensign 1983	Montana	38	0.54	
		41		
		45		
Gaines 1985	North Dakota	16		
Gilmer and Stewart 1983	North Dakota	17		
Harmata et al. 1991	Kevin, Montana	7		
Howard and Wolfe 1976	Idaho, Utah	21-49		
Knight and Smith 1982	Washington		1.61	
Lardy 1980	Oregon	10		1.9
Lokemoen and Duebbert 1976	South Dakota	17		2.6±2.0
Myers 1987	Montana	6-7		2.7±0.44
Ramakka and Woyewodzic 1993	New Mexico	211		
Restani 1991	Montana	21	1.13	2.82±2.44
			1.03	2.98±1.40
Smith and Murphy 1978	Utah	2		
Thurow and White 1983	Idaho			2.3
Wittenhagen 1992	Montana	35		
		30		
Woffinden and Murphy 1989	Utah	9-15		
Van Horn 1993 (this study)	Kevin, Montana	8	0.11	1.01±0.5

[a] Density values are the actual values reported or were calculated from source material.
[b] R-values were calculated as in Clark and Evans (1954).

Table 17. Ferruginous hawk reproductive success and productivity rates reported in the literature and observed on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Source	Success rate of occupied nests (%)	# fledged per occupied nest	# fledged per successful nest
Blair and Schitoskey 1982	72	1.89	
	82	2.29	
Call and Tigner 1991			2.6
Cottrell 1981		1.6	2.59
Craighead and Mindell 1981	88		
	40		
Ensign 1983	25.0	0.42	1.67
	27.3	0.45	1.67
Fitzner et al. 1977	33	1.8	
	50	2.5	
Gaines 1985	62.4	1.6	
Gilmer and Stewart 1983	64.0-75.9	2.2	
Harmata et al. 1991		0.87[b]	
Howard and Wolfe 1976	83.1	1.0	
		1.9	
Knight and Smith 1982	42.9	1.0	2.6
Lardy 1980		3.2	
Lokemoen and Duebbert 1976		1.5	1.8
MacLaren 1986	94	2.5	2.6
	92	2.5	2.7
Myers 1987	57.9	1.45	
	70.6	1.85	
Olendorff 1973	70.4		2.59
Platt 1971	91.7	3.41	3.7
Ramakka and Woyewodzic 1993	67	1.8	2.4
Restani 1991	67.0	1.77	2.65
Schmutz 1977, Schmutz et al. 1980	46-68		2.6
Steenhof and Kochert 1988	63.0	1.2	
	68.0	1.9	
White and Thurow 1985	70.0	1.70	2.43
	64.0	1.71	2.67
Wittenhagen 1992	63.6		1.86
	68.0		2.71
Woffinden and Murphy 1989		1.7	1.5
median values	67	1.8	2.6
Van Horn 1993 (this study)	47	1.1	2.3

Avg = 1.75

[a] These are the actual values reported or else they were calculated from source information.

[b] This is the value calculated from source information for the Kevin Rim area in 1990.

Table 18. Prairie falcon reproductive success and productivity rates reported in the literature and observed on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Source	Success rate of occupied eyries	# fledged per occupied eyrie	# fledged per successful eyrie
Becker and Ball 1983			4.5
Boyce 1986			3.26
Eakle 1984			3.3
			3.0
Edwards 1973		1.6	
Enderson 1964		1.2	
Harmata et al. 1991		0.8[b]	
MacLaren 1986	70	2.3	2.5
	75	3.2	4.1
Ogden and Hornocker 1977	83	3.1	3.7
Olendorff 1973	88.8	3.42	3.71
Platt 1971		4.5	4.5
Platt 1981	80	2.51	3.67
median value	81.5	2.51	3.3
Van Horn 1993 (this study)	71	1.9	2.7

[a] These are the actual values reported or else they were calculated from source information.

[b] This is the value calculated from source information for the Kevin Rim area in 1990.

APPENDIX C

THEORETICAL AND OBSERVED NEST DEFENSE

Montgomerie and Weatherhead (1988:170) defined nest defense as "behavior that decreases the probability that a predator will harm the contents of the nest (eggs or chicks) while simultaneously increasing the probability or injury or death to the parent" and summarized current theories of nest defense. One theory predicts that nest defense should increase as parental renesting potential decreases, and should peak when this potential is zero. Ferruginous hawks are not known to renest in the same season so this theory would not predict a change in their nest defense throughout the season. Another theory predicts that experienced parents should ignore non-threatening situations because their young are less likely to be lost to other causes, and should react aggressively to any situation that truly threatens nest contents. A third theory predicts that nest defense should vary with the probability that offspring will survive to reproduce. These theories and some raptor biologists (Fyfe and Olendorff 1976) predicted that raptor nest defense intensity should increase throughout the nesting period.

Several studies indicated that nest defense increased throughout the nesting season in passerines (Weatherhead 1979, Andersson et al. 1980, Bierman and Robertson 1981, Knight and Temple 1986a). Among raptors this has only been reported in English tawny owls (Strix aluco) and Minnesota bald eagles (Haliaeetus leucocephalus) (Fraser et al. 1985, Wallin 1986). Knight and Temple (1986b) hypothesized that many observed nest defense increases might be due to a loss of fear of humans and positive reinforcement of the defending adults by researchers themselves, and they suggested that more rigorous methodology be employed in such studies. Westneat (1989) was able to discount the impact of research activities and still found an increasing trend in indigo bunting (Passerina cyanea) nest defense.

Established theories supported by field evidence predict that ferruginous hawk and prairie falcon nest defense in the Kevin Rim area should either increase or decrease throughout the nestling period. Ferruginous hawks and prairie falcons in the Kevin Rim area did not show any trends in nest defense during the nestling period, so the evidence does not support any one current nest defense theory more than the others. Andersen (1990) found a similar lack of trend in red-tailed hawk dive rates, so perhaps these nest defense theories are not applicable to diurnal raptors.

Young raptors differ from passerine young in that their self-defense abilities increase with age, while the self-defense abilities of young passerines are not likely to significantly change with age (Wallin 1986). Wallin (1986) predicted that raptor nest defense should decrease with nestling age because the potential benefit to parents of nest defense declines as nestlings become more capable of defending themselves and their value to a predator decreases. This was observed in eastern screech-owls (Otus asio) by Sproat and Ritchison (1993). Ferruginous hawk and prairie falcon reactions to humans did decline after young fledged. This may support Wallin's (1986) theory of nest defense. Adult ferruginous hawks appeared to defend fledged young more aggressively than the empty (post-fledging) nest structure. Individual variation in nest defense was great and individual ferruginous hawks (identified at a few nests by plumage differences) did not show any trends in nest defense over time. This variability in nest defense was reported for ferruginous hawks in Idaho by Powers (1981). In addition, there were many complicating factors which were not controlled in this study (i.e. time since last meal, wind velocity, temperature). Past experience with human nest intrusion may influence raptor nest defense. Interactions with humans while foraging or while on winter range also may influence nest defense in long-lived species like ferruginous hawks.

If improved nest defense is an ultimate cause of reversed sexual dimorphism (Snyder et al. 1976) then ferruginous hawks should divide nest defense more evenly between genders than the more dimorphic rough-legged hawks (Snyder et al. 1976). Female ferruginous hawks were more aggressive (nest defense was divided more evenly) in the Kevin Rim area, southeast Montana, and Idaho (Ensign 1983, Powers 1981) than female rough-legged hawks in Sweden (Andersson and Wiklund 1987). Ferruginous hawk behavior is consistent with the theory that improved nest defense is a factor maintaining reversed sexual dimorphism.

APPENDIX D

FERRUGINOUS HAWK GENDER AND PLUMAGE COLOR

Nestlings were not banded in 1991. Therefore, their gender was not determined. In 1992, 11 of 19 ferruginous hawk nestlings which were old enough to band and determine gender (by tarsal width) were male. In 1991, 1 of 18 ferruginous hawk nestlings had dark plumage. The frequency of dark nestlings increased in 1992, when 3 of 33 nestlings were dark. Five of 18 adult ferruginous hawks breeding in 1991 were dark, but only 3 of 31 had dark plumage in 1992. Dark nestlings were found in 3 nests defended by mixed pairs (1 light adult, 1 dark adult) but never in nests defended by 2 light adults. In 1991, 2 adjacent nests defended by mixed pairs contained both light and dark nestlings, but in 1992 such nests had only dark nestlings.

Schmutz and Schmutz (1981) reviewed the reports of dark-phase ferruginous hawks and found frequencies ranging from 1.6% to 9.4% (Lokemoen and Duebbert 1976, Schmutz and Schmutz 1981). In 1991, the frequency of dark plumage (28%) was higher in adults than previously recorded, but occurrence among nestlings (5.9%) and 1992 adults (9.7%) was similar to that recorded elsewhere. If Schmutz and Schmutz (1981) were correct in suspecting that dark plumage in ferruginous hawks is a dominant trait, then dark nestlings should only occur when at least one parent is dark colored and most young from light-dark matings should be dark as well. The circumstances surrounding the dark phase nestlings in this study (dark phase young found only in mixed-pair nests) supported this hypothesis. There were too few nests involved (N = 5) to determine if ferruginous hawk plumage color is gender-linked. Apostatic selection, or "selection for its own sake" (Paulson 1973), has been proposed as a mechanism maintaining different plumage types in predator populations and may explain the presence of 2 distinct color types in this and other ferruginous hawk populations (Paulson 1973).

APPENDIX E

NESTING, MORTALITY, AND FORAGING BEHAVIOR OF OTHER RAPTORS

In 1991, in addition to ferruginous hawk nests and prairie falcon eyries there were 3 large raptor nests in the study area: 1 red-tailed hawk (Buteo jamaicensis) nest, 1 golden eagle nest, and 1 Swainson's hawk nest. In 1992, there were 5 other raptor nests: 3 red-tailed hawk nests, 1 golden eagle nest, and 1 Swainson's hawk nest. Probably there were northern harrier (Circus cyaneus) nests in the area both years but appropriate habitats (CRP lands and fallow croplands) were not searched.

No golden eagles, red-tailed hawks, or Swainson's hawks were known to have fledged in the area in 1991. Two golden eagles, 1 red-tailed hawk, and 2 Swainson's hawks were fledged in the area in 1992.

An adult Swainson's hawk found in a roadside ditch in 1992 was too decomposed to allow necropsy. A partially eaten, decomposed male northern harrier was found 150 m from an active ferruginous hawk ground nest in 1992. The unscavenged body of an adult female great horned owl was found near her nest, probably killed by a very defensive female red-tailed hawk nesting nearby. A decomposed, oil-covered raptor tentatively identified as a northern harrier was found 125 m from an evaporation pit east of the study area in 1992.

Swainson's hawks flew significantly less and perched on fenceposts (Table 19) significantly more than other species (Appendix B Table 14). Northern harriers flew significantly more and used all perches (Table 19) significantly less than other species (Appendix B Table 14). Red-tailed hawks flew and perched on outcrops and the ground (Table 19) significantly less ($P < 0.1$), and perched on oil pumps and powerpoles (Table 19) significantly more than other species (Appendix B Table 14). The golden eagle sample size was too small ($N = 9$) for comparison.

Table 19. Perch use (%) by foraging ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Species	N	Perch type Flying	Ground	Fencepost	Powerpole	Oilpump	Outcrop
Ferruginous hawk	114	18.1	31.0	6.0	35.3	1.7	7.8
Swainson's hawk	58	8.6	12.1	43.1	32.8	1.7	1.7
Northern harrier	55	78.2	7.3	14.5	0.0	0.0	0.0
Red-tailed hawk	24	4.2	8.3	37.5	41.7	8.3	0.0

[a] Based on 375 km^2 of roadsides surveyed for raptor use over both years.

Swainson's hawks and northern harriers used roads in proportion to their availability (Table 20). Red-tailed hawks were found along primary roads significantly more than expected and tertiary roads significantly less than expected (Appendix B Table 15).

Table 20. Availability and use (%) of roadsides by foraging ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Species	N	Road type Primary	Secondary	Tertiary	Chi-square p-value
Ferruginous hawks	114	15	83	3	P<0.005
Swainson's hawks	58	33	45	22	0.1<P<0.95
Northern harriers	55	24	58	18	0.1<P<0.95
Red-tailed hawks	24	57	43	0	P<0.005
Roadsides available		27	55	18	

[a] Based on 375 km^2 of roadsides surveyed for raptor use over both years.

Raptors commonly seen along roadsides used habitats significantly different than the proportional occurrence of each habitat (Table 21). Swainson's hawks used rangelands significantly less and croplands significantly more than expected. Northern harriers used rangelands and oilfields significantly less and fallow and crop habitats significantly more than expected. Red-tailed hawks used croplands significantly less than expected (Appendix B Table 15).

Table 21. Availability and use (%) of roadside habitats by ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Species	N	Habitat type: Range	Fallow	Crop	Oil	Chi-square p-value
Ferruginous hawks	114	61	2	6	31	0.005<P<0.01
Swainson's hawks	58	48	7	31	14	P<0.005
Northern harriers	55	38	38	21	4	P<0.005
Red-tailed hawks	24	54	13	0	33	0.05<P<0.1
Habitats available		64	7	8	21	

[a] Based on 375 km^2 of roadsides surveyed for raptor use over both years.

Red-tailed hawks showed the least variation in response to humans and allowed human or vehicular presence much nearer than other raptors before reacting. Swainson's hawks and northern harriers were intermediate in reaction to humans (Table 22).

Table 22. Distances (m) at which roadside ferruginous hawks, Swainson's hawks, northern harriers, and red-tailed hawks reacted to human or vehicular presence on the Kevin Rim study area, Montana, 1991 and 1992.[a]

Species	N	Distance: mean	SD	median	Percentile: 75th	90th	95th
Ferruginous hawks	59	45.6	37.1	35	60	75	150
Swainson's hawks	40	29.4	26.6	25	40	45	80
Northern harriers	17	37.7	21.3	40	45	60	80
Red-tailed hawks	15	17.9	18.7	11	15	65	60

[a] Based on 375 km^2 of roadsides surveyed for raptor use over both years.

Bechard (1982) believed that Swainson's hawks' choice of forage site was influenced by vegetative characteristics, weather conditions, and the number of prey present. Swainson hawks' greater use of croplands was made possible by their better aerodynamics, and their lower use of rangelands reflected the lower number of fenceposts in this habitat. Northern harriers are aerial foragers (Johnsgard 1990:158), which was reflected by the fact that they were most often seen flying over fallow lands and CRP. Their low use of rangelands and oilfields was probably due to the lower number of microtines present for their use as prey (Craighead and Craighead 1969:42,402, Clark and Ward 1974, Hamerstrom 1986:143), but their relatively great avoidance of humans may also have been a factor in their low use of oilfields.

Red-tailed hawk foraging distribution varied with perch distribution and varied inversely with vegetation density. Their high use of primary roads could be attributed to the presence of fenceposts (often wooden) and powerlines along such roads, and on their tolerance of human presence. Their low use of secondary and tertiary roads was most likely due to fewer perches along such roads. After July, croplands had the densest vegetative cover of any widespread habitat in the area and were avoided by red-tailed hawks.

Golden eagles were not common nesters in the study area so it was not surprising that they were rarely seen along roadsides. Neither Swainson's hawks nor red-tailed hawks were common nesters in the study area, yet both were commonly seen foraging along roadsides. This may indicate that roadside habitats were important for these 2 species. Alternatively, there may have been foraging non-breeding Swainson's hawks and red-tailed hawks attracted to the study area from other areas by the relative abundance of perches in roadside habitats.