Breeding ecology of ferruginous hawks at the Kevin Rim in northern Montana
by James Richard Zelenak

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:
In 1993-94,I investigated factors influencing nest survival and productivity of ferruginous hawks in northern Montana and I estimated juvenile post-fledging survival using radio telemetry. A 170.9 km2 area at the Kevin Rim Key Raptor Area (BLM) contained 24 occupied ferruginous hawk territories in both 1993 and 1994; a breeding density of 7.12 km2/pair. Nest survival was 0.75 from occupancy to egg-laying (SE = 0.06, n = 48), 0.86 from egg-laying to hatching (SE = 0.06, n = 36), and 0.65 from hatching to fledging (SE = 0.09, n = 31). Sixty-five percent of occupied nests survived to hatching (SE = 0.07, n = 48), and 42% survived to fledging (SE = 0.07, n = 48). Mean productivity values for the 2 years combined were 2.10 eggs (SE = 0.21), 1.75 nestlings (SE = 0.21), and 0.96 young fledged (SE = 0.19) per occupied territory (n = 48). Mean clutch and brood sizes were 2.81 (SE = 0.16, n - 36) and 2.71 (SE = 0.16, n = 31), respectively, and mean number of young fledged/successful nest was 2.30 (SE = 0.21, n = 20). Twenty-three of 27 radio-marked juveniles survived to disperse from the study area (S = 0.85, SE = 0.07). Univariate and multivariate analyses indicated that ferruginous hawk nest survival and productivity were related to proximity of nests to cultivated fields, active oil wells, secondary roads, and other breeding raptors, as well as to the number/intensity of these variables within 1.6 km of occupied nests. Human disturbance related to mineral development and agricultural activities did not appear to negatively impact breeding ferruginous hawks. However, increases in these activities could pose a potential threat and should be discouraged. There is reason to believe that the ferruginous hawk population at the Kevin Rim has had inadequate productivity to sustain itself during the past 5 years. Low prey availability may be responsible for poor reproductive success. Further research is needed to determine if the population's growth rate remains negative over a longer period. If reproductive rates remain low, management plans to increase prey populations may be necessary.

BREEDING ECOLOGY OF FERRUGINOUS HAWKS AT THE KEVIN RIM IN NORTHERN MONTANA

by

James Richard Zelenak

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

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 1996

APPROVAL

of a thesis submitted by

James Richard Zelenak

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.

Dr. Jay J. Rotella — (Signature) — 1/18/96 Date

Approved for the Department of Biology

Dr. Ernest R. Vyse — (Signature) — 1/18/96 Date

Approved for the College of Graduate Studies

Dr. Robert L. Brown — (Signature) — 2/3/96 Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University-Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature James R. Zelenak

Date 1/18/96

ACKNOWLEDGMENTS

This research was funded through a Challenge Cost Share between the Bureau of Land Management (BLM) and Montana State University, Bozeman (P.O. 1422-E950-P3-0135, Ref. No. MT067-RQ3-019). I thank Tad Day, BLM, Great Falls Resource Area, for assistance in obtaining funding for this project. Dennis Flath, Montana Department of Fish, Wildlife, and Parks, Nongame Division, provided a vehicle, travel expenses, and encouragement. Drs. A. R. Harmata, L. R. Irby, T. E. McMahon, and J. J. Rotella served as graduate committee members. Dr. Rotella served as graduate committee chairperson and provided guidance throughout this project and assisted greatly with data analysis and editing. Dr. Harmata generously provided radio-telemetry and banding equipment, and belayed his son, Peter, down sheer cliffs to capture juvenile hawks. Dr. D. L. Gustafson created the digital elevation model of the Kevin Rim. K. W. Wittenhagen provided a much-appreciated collection of difficult-to-find ferruginous hawk literature. Thanks to R. C. Van Horn, E. C. Atkinson, and M. Restani for insights and discussions on raptor biology, and to K. Podruzny for statistical assistance. Thanks also to Field Technicians Geoff FitzGerald and Cecil Tharp for their dedication to field work, and to Dee Topp, who helped immensely with administrative details and allowed me to use her computer. Finally, I would like to thank my wife, Eva, for much-needed technical assistance and moral support, especially during the final stages of this project.

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In 1993-94, I investigated factors influencing nest survival and productivity of ferruginous hawks in northern Montana and I estimated juvenile post-fledging survival using radio telemetry. A 170.9 km^2 area at the Kevin Rim Key Raptor Area (BLM) contained 24 occupied ferruginous hawk territories in both 1993 and 1994; a breeding density of 7.12 km^2/pair. Nest survival was 0.75 from occupancy to egg-laying (SE = 0.06, n = 48), 0.86 from egg-laying to hatching (SE = 0.06, n = 36), and 0.65 from hatching to fledging (SE = 0.09, n = 31). Sixty-five percent of occupied nests survived to hatching (SE = 0.07, n = 48), and 42% survived to fledging (SE = 0.07, n = 48). Mean productivity values for the 2 years combined were 2.10 eggs (SE = 0.21), 1.75 nestlings (SE = 0.21), and 0.96 young fledged (SE = 0.19) per occupied territory (n = 48). Mean clutch and brood sizes were 2.81 (SE = 0.16, n = 36) and 2.71 (SE = 0.16, n = 31), respectively, and mean number of young fledged/successful nest was 2.30 (SE = 0.21, n = 20). Twenty-three of 27 radio-marked juveniles survived to disperse from the study area ($\hat{S}$ = 0.85, SE = 0.07). Univariate and multivariate analyses indicated that ferruginous hawk nest survival and productivity were related to proximity of nests to cultivated fields, active oil wells, secondary roads, and other breeding raptors, as well as to the number/intensity of these variables within 1.6 km of occupied nests. Human disturbance related to mineral development and agricultural activities did not appear to negatively impact breeding ferruginous hawks. However, increases in these activities could pose a potential threat and should be discouraged. There is reason to believe that the ferruginous hawk population at the Kevin Rim has had inadequate productivity to sustain itself during the past 5 years. Low prey availability may be responsible for poor reproductive success. Further research is needed to determine if the population's growth rate remains negative over a longer period. If reproductive rates remain low, management plans to increase prey populations may be necessary.

INTRODUCTION

Distribution and Status

The ferruginous hawk (Buteo regalis), the largest North American *Buteo* or soaring hawk, is associated with open, dry grassland and shrubsteppe habitats in the western U.S. and southern Canada (Bendire 1892, Cameron 1914, Bent 1937, Brown and Amadon 1968). Slightly larger than red-tailed hawks (B. jamaicensis), ferruginous hawks occur in 2 color phases; the more common light phase, and a dark morph that usually represents 1 to 10% of breeding populations (Schmutz and Schmutz 1981, Olendorff 1993). The species breeds in 17 states and 3 Canadian provinces (Olendorff et al. 1989, Olendorff 1993). The breeding range extends from North Dakota south to northwest Texas, west to eastern Oregon and Washington, and north into the prairie provinces of Alberta, Saskatchewan, and southwest Manitoba (Fig. 1). Ferruginous hawks winter in the southwestern U.S. and northern Mexico (Salt 1939, Harmata 1981, Gilmer et al. 1985, Schmutz and Fyfe 1987, Warkentin and James 1988) but may remain year-round on some southern portions of the breeding range (Smith and Murphy 1978, Schmutz and Fyfe 1987, Johnsgard 1990: 248).

Ferruginous hawks are protected under the federal Migratory Bird Treaty Act and are under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS 1992). The Bureau of Land Management (BLM) and other federal agencies are mandated to manage public lands for multiple-use, including the protection of raptor habitat and breeding

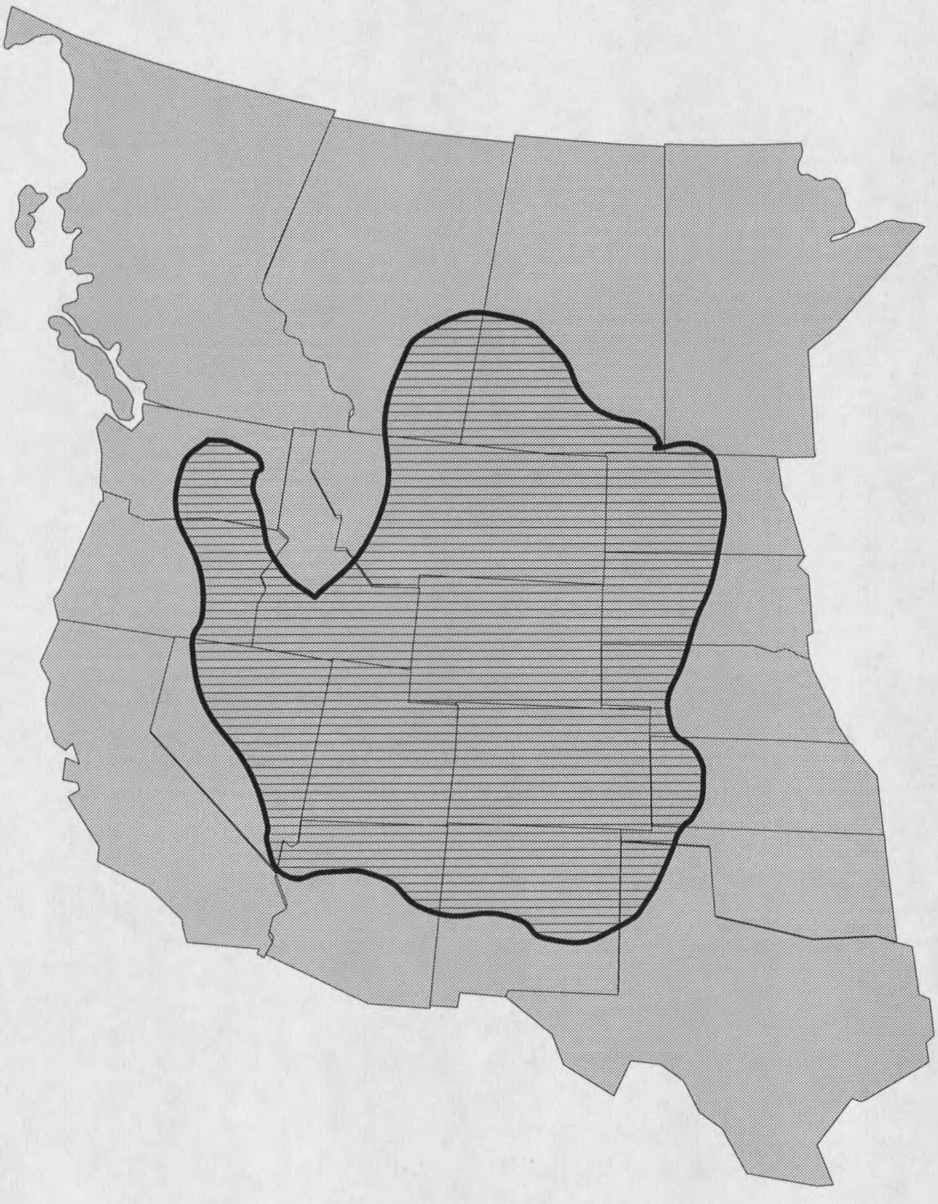

Figure 1. Breeding range of ferruginous hawks (after Olendorff 1993).

populations (Olendorff et al. 1989). A petition to list the ferruginous hawk as endangered (Ure et al. 1991) was rescinded by the USFWS (1992), however, the species remains a Category II Candidate for listing under the Endangered Species Act.

Some breeding populations of ferruginous hawks appear to be stable or increasing (Schmutz et al. 1984, Schmutz 1987b, Schmutz and Hungle 1989, USFWS 1992, Olendorff 1993), but others have declined, often dramatically (Powers and Craig 1976; Woffinden and Murphy 1977, 1989; Bechard 1981; Houston and Bechard 1984; Zelenak and Rotella 1994). Houston and Bechard (1984) believed that ferruginous hawks in Saskatchewan had declined to 10 to 20% of pre-settlement levels by 1960 and that as much as 40% of the species' original range was no longer occupied. Conversely, Warkentin and James (1988) reported a significant increase in the number of ferruginous hawks recorded during Christmas bird counts between 1952 and 1984, with the largest increase occurring between 1973 and 1984. Current estimates of total population size range from approximately 5,800 to 15,000 individuals (Ure et al. 1991, USFWS 1992, Olendorff 1993). In Montana, 175 to 250 pairs are estimated to breed (Olendorff 1993), but many areas of potentially suitable habitat within the state have not yet been surveyed (Atkinson 1995). The Montana Department of Fish, Wildlife, and Parks has classified the ferruginous hawk as a Species of Special Concern (Flath 1991).

Factors Affecting Breeding Success

Several researchers have proposed that the breeding range and the number of breeding pairs of ferruginous hawks have declined (Fyfe 1976, Bechard 1981, Houston and Bechard 1984, Woffinden and Murphy 1989, Ure et al. 1991). A combination of factors, including loss of grassland habitat to large-scale cultivation, invasion of aspens (Populus sp.) into prairies due to fire suppression, range improvement practices, energy development, urbanization, and other human activities are thought to be responsible for declines (Lokemoen and Duebbert 1976; Blair and Schitoskey 1982; Houston and Bechard 1984; Schmutz 1984, 1987a, 1989; Olendorff 1993). Remaining suitable habitat may be threatened by increases in such activities (Howard and Wolfe 1976, Gilmer and Stewart 1983, Olendorff et al. 1989, Andersen et al. 1990).

Ferruginous hawks rarely nest in areas dominated by croplands (Howard and Wolfe 1976; Lokemoen and Duebbert 1976; Cottrell 1981; Blair and Schitoskey 1982; Gilmer and Stewart 1983; Schmutz 1984, 1987a, 1989; Olendorff et al. 1989). They are also sensitive to disturbances related to human activities near nest sites (Weston 1969, Blair and Schitoskey 1982, Ensign 1983, Gaines 1985, White and Thurow 1985, Andersen et al. 1990) and may abandon nests after a single disturbance if eggs have not yet hatched (Snow 1974, Howard 1975, Fyfe and Olendorff 1976, Fitzner et al. 1977, Blair 1978, Call 1979, Olendorff et al. 1989). Because the species is not known to renest after a clutch is lost (Woffinden and Murphy 1977), disturbances near nest sites during territory establishment or incubation could remove potential breeders from the breeding population.

Numbers of breeding pairs of ferruginous hawks fluctuate in response to changes in prey populations (Powers and Craig 1976; Woffinden and Murphy 1977, 1989; Smith et al. 1981; Schmutz and Hungle 1989). Because breeding ferruginous hawks often depend primarily upon a single prey species, usually jackrabbits (Lepus sp.) (Howard and Wolfe

1976; Woffinden and Murphy 1977, 1989; Smith et al. 1981) or ground squirrels (Spermophilus sp.) (Lardy 1980, Schmutz et al. 1980, Cottrell 1981, Gilmer and Stewart 1983, Schmutz and Hungle 1989), reductions in these key prey species can result in decreased nesting success and lowered reproductive rates (Howard and Wolfe 1976; Woffinden and Murphy 1977, 1983, 1989; Ensign 1983; Olendorff 1993).

Justification and Objectives

The Kevin Rim (Fig. 2), a series of sandstone cliffs in northern Montana, supports one of the highest concentrations of breeding raptors in the U.S. (DuBois 1988). Because of the unusually high diversity and density of breeding raptors supported by the Rim and surrounding grasslands, the BLM, which manages a portion of the area, has designated the Rim a Key Raptor Area (Olendorff et al. 1989) and an Area of Critical Environmental Concern (Williams and Campbell 1988). In addition to ferruginous hawks, the Rim and adjacent badlands and grasslands support breeding prairie falcons (Falco mexicanus), American kestrels (F. sparverius), red-tailed hawks, Swainson's hawks (B. swainsonii), golden eagles (Aquila chrysaetos), great-horned owls (Bubo virginianus), and burrowing owls (Athene cunicularia). Northern harriers (Circus cyaneus) and short-eared owls (Asio flammeus) also occur on the area.

DuBois (1988) first documented the Kevin Rim as an important breeding area for ferruginous hawks and other raptor species. She located, mapped, and photographed ferruginous hawk nest sites, noted productivity when possible, and estimated breeding densities on BLM lands surrounding the Rim. In 1990, Harmata (1991) estimated

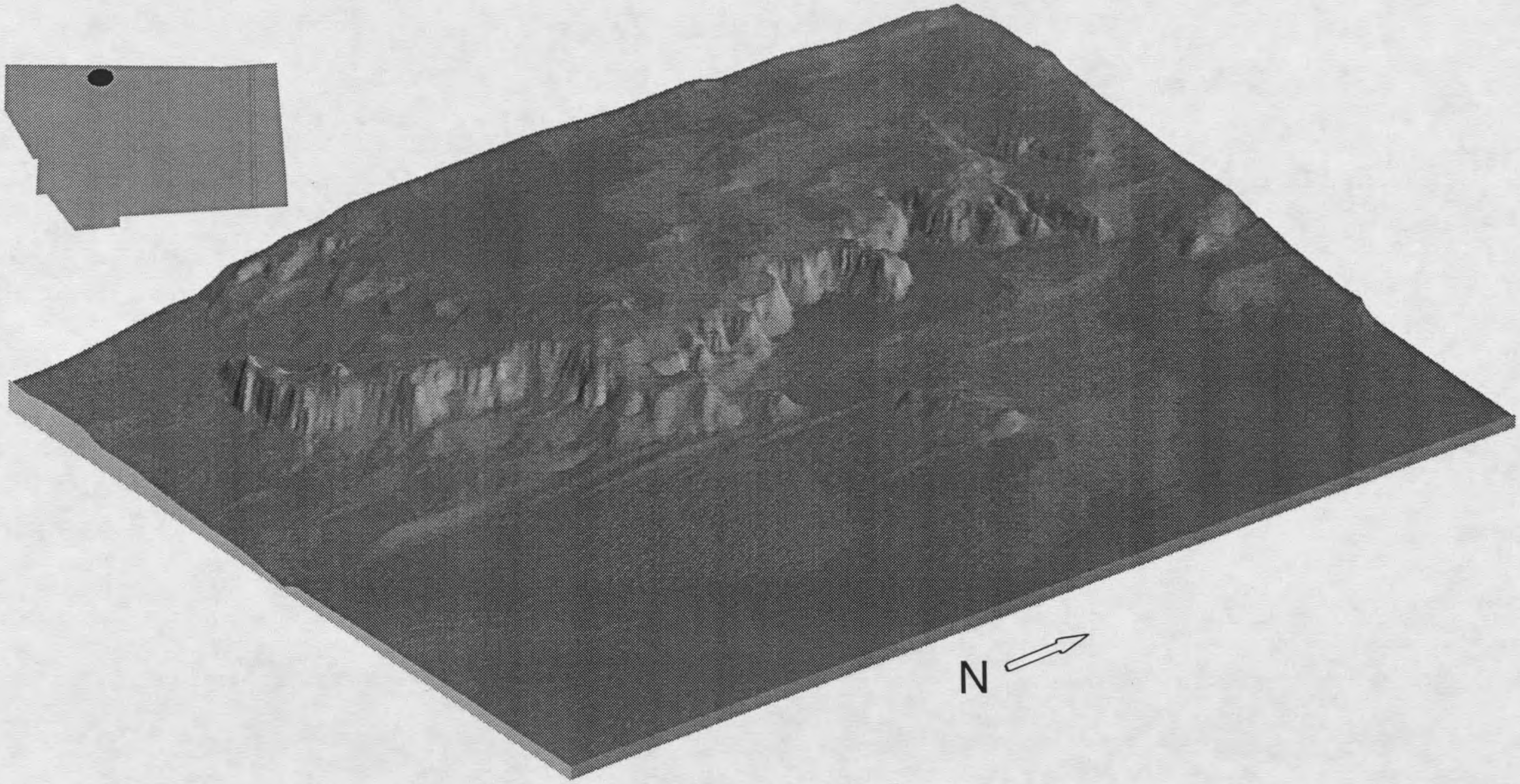

Figure 2. Digital-elevation model of the Kevin Rim. View is from 127°, altitude angle is 30°, and vertical exaggeration is 5:1. South-to-north axis represents 19.0 km.

breeding density, recorded nesting chronology, gathered prey remains, and estimated prey density and availability at the Rim. He also recorded physical characteristics of occupied nests, radio-marked 2 ferruginous hawks (1 adult male and 1 juvenile female) to investigate home range and dispersal, and investigated the impacts of proximity of nests to a variety of Habitat Component Variables (HCVs) on nest-site selection and reproductive success (Harmata 1991). In 1991 and 1992, Van Horn (1993) approached occupied breeding sites on foot to measure reaction distances to human disturbances, recorded reactions of roadside-foraging raptors to passing vehicles, and estimated availability of ground squirrels (S. richardsonii) to foraging raptors. Both Harmata (1991) and Van Horn (1993) investigated impacts of disturbance related to oil development at the Kevin Rim.

Previous research efforts provide valuable data on raptor breeding activity and the impact of oil development on raptor reproductive success at the Kevin Rim and contribute important information on breeding dynamics of ferruginous hawks. They have also laid the foundation of what should become, with continued research and monitoring, an important source of long-term raptor breeding data, necessary to detect trends in breeding populations (Olendorff 1993). However, there are several important aspects of ferruginous hawk breeding ecology that have not yet been adequately addressed. Early-season territory occupancy and subsequent rates of nest survival have not been adequately documented at the Rim. Little is known about survival of juveniles from fledging until dispersal from breeding areas (Konrad and Gilmer 1986), an important parameter in determining if particular breeding areas are sources or sinks for ferruginous hawk populations. Finally, the influence of habitat, land-use, and sources of disturbance on ferruginous hawk nest success and productivity have not been completely quantified at the Kevin Rim.

The goal of this study was to address these gaps in our understanding of the breeding ecology of ferruginous hawks and to contribute to the long-term database that has been initiated at the Kevin Rim. My objectives were to: 1) document early-season territory-occupancy and monitor all occupied territories until failure or fledging, 2) determine causes of nest failure, 3) calculate productivity and nest survival for several stages of the breeding season, 4) estimate juvenile post-fledging survival, 5) determine the effects of habitat, land-use, disturbance, competition, and physical characteristics of nest sites on nest survival and productivity, and 6) estimate density of prey species in different habitat types.

STUDY AREA

The Kevin Rim in Toole County, northern Montana (48° 47' N, 112° 2' W), is a prominent series of sandstone cliffs and outcrops that extends 17.5 km south-to-north beginning 8.0 km northwest of the town of Kevin. My 170.9 km^2 study area encompassed the main Rim and an area of badlands 3.2 km east of the Rim. I defined the study area as all sections (2.6 km^2) of land containing rimrock or other suitable nesting substrates and all additional sections containing land within 1.6 km of suitable nesting substrates (Fig. 3). The study area included 119.2 km^2 on which ferruginous hawks and other raptors have been monitored during previous research efforts at the Rim (DuBois 1988, Harmata 1991, Van Horn 1993) as well as an additional 51.7 km^2 of previously unsurveyed, mostly private land north of the traditional study area. Elevation ranged from 1,014 to 1,306 m, and cliffs associated with the Rim attained heights of 35 m (Harmata 1991).

Seventy-eight percent of land adjacent to the Rim was comprised of grassland and grassland-sagebrush (Artemisia cana) rangelands, 20% was croplands, primarily unirrigated wheat fields, and 2% was Conservation Reserve Program (CRP) lands (Fig. 4). Cattle grazing occurred on nearly all uncultivated land. Trees were rare on the study area and occurred only as small stands of aspen (Populus tremuloides) and cottonwoods (Populus sp.) in a few narrow, isolated draws (DuBois 1988). Vegetation at the Kevin Rim has been described in detail by DeVelice (1991).

The study area contained 162 active (producing) oil wells, 27 active gas wells, and an additional 316 abandoned or inactive wells associated with the Kevin-Sunburst Oil

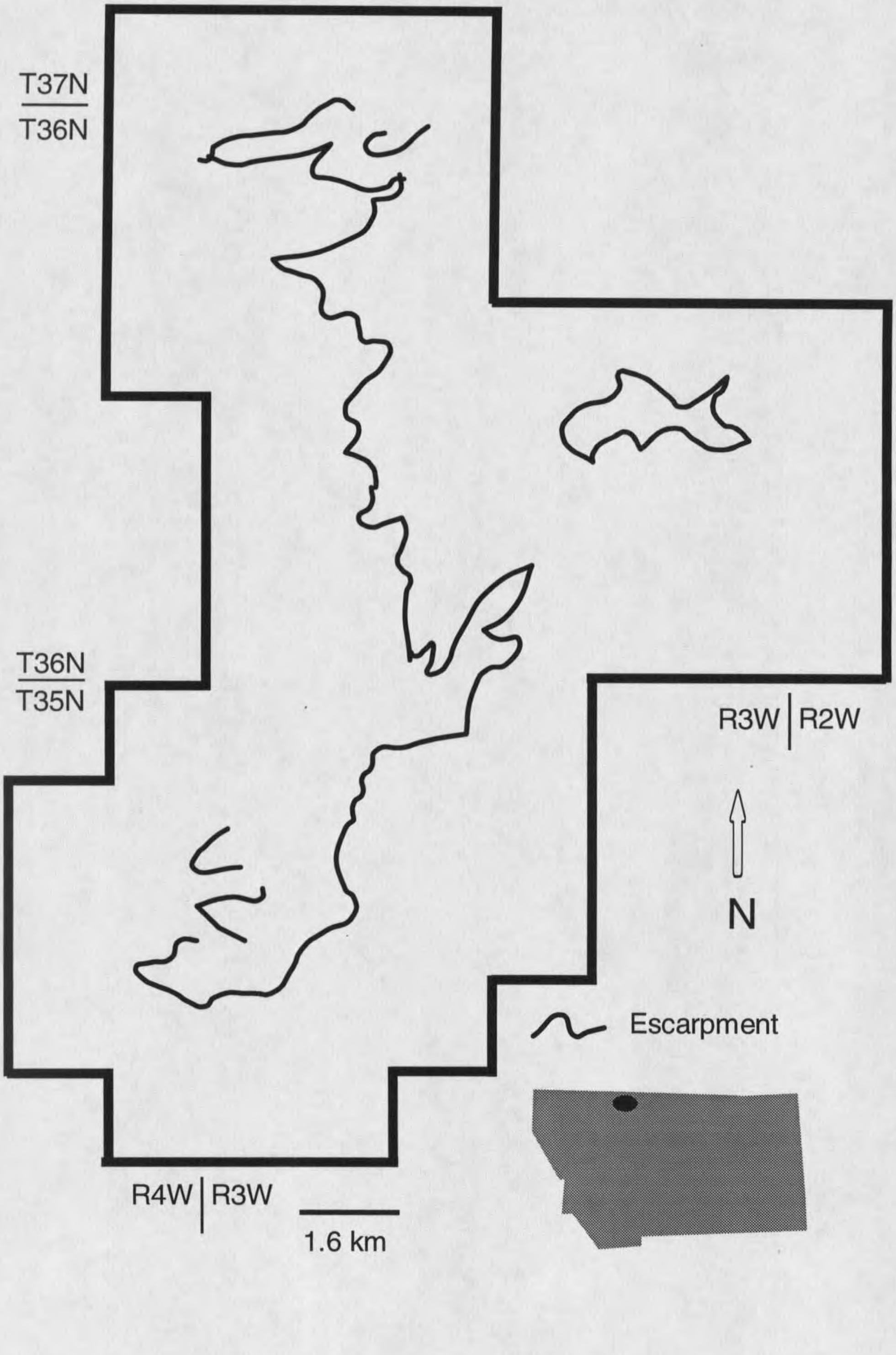

Figure 3. Kevin Rim study area 1993-1994, showing major lines of topographic relief.

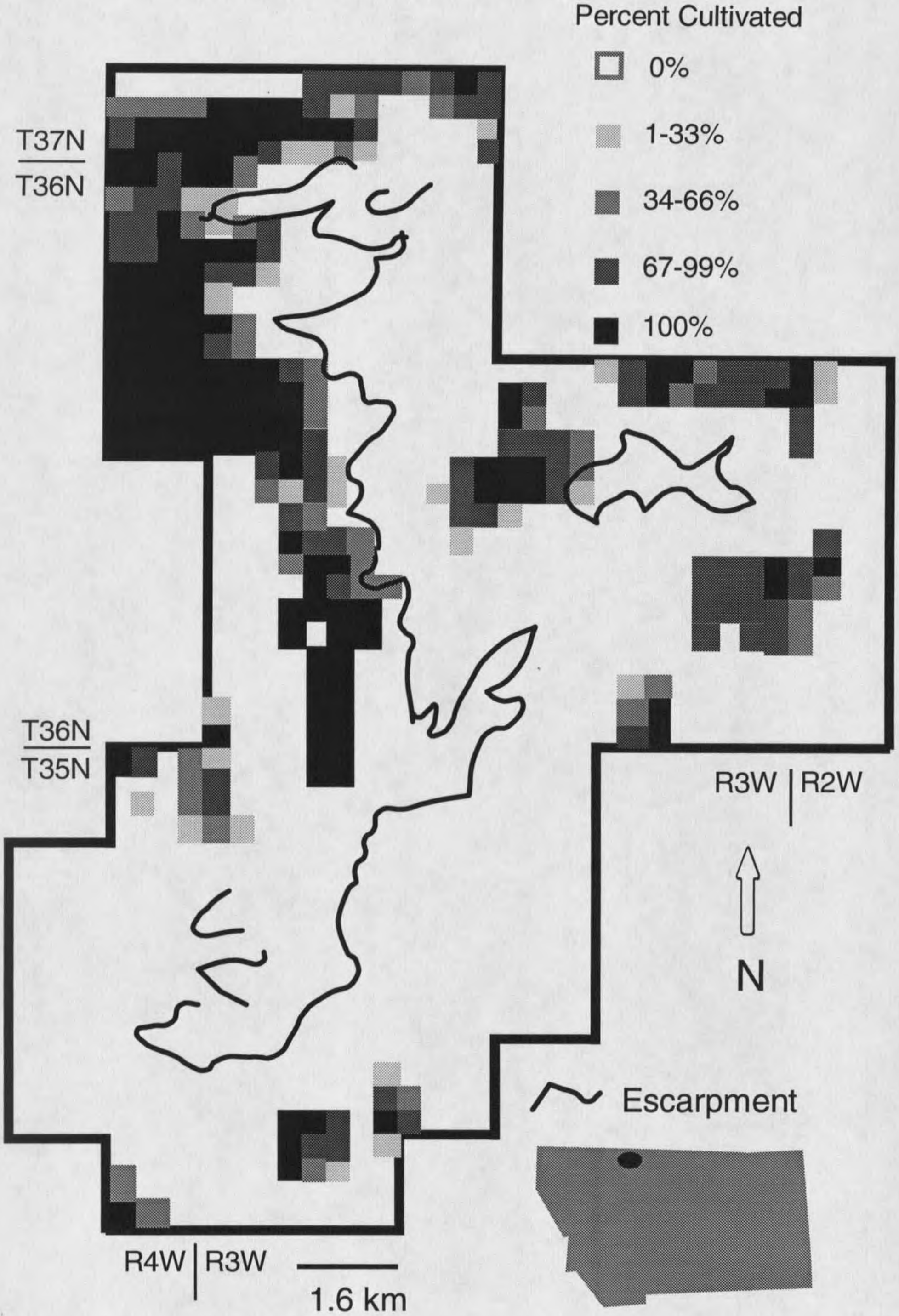

Figure 4. Locations and intensity of cultivation at the Kevin Rim, 1993-1994.

Field (Fig. 5). There were 39.7 km of primary (improved dirt) roads and an extensive network of secondary (unimproved dirt) roads associated with oil fields and croplands. BLM and State lands comprised 29.6 km^2 (17.3%) and 25.7 km^2 (15.1%), respectively. The remaining 115.6 km^2 (67.6%) was privately-owned (Fig.6).

Between 1951 and 1994, precipitation during the ferruginous hawk breeding season (April-August) averaged 221 mm at the Sunburst, Mont. weather station in the northeastern corner of the study area (Climatedata 1995). In 1993, April-August precipitation was 464 mm; 210% of the long-term average. Precipitation in June 1993 (131 mm) was nearly twice the long-term average (66 mm), and July (169 mm) and August (104 mm) 1993 were the wettest recorded since 1951 (long-term averages were 40 mm and 39 mm for July and August, respectively). In 1994, 161 mm of precipitation were recorded between April and August; 73% of the long-term average. Temperatures during 1993 and 1994 were within the long-term range of minimum (-3°C) and maximum (31°C) April-August temperatures (Climatedata 1995).

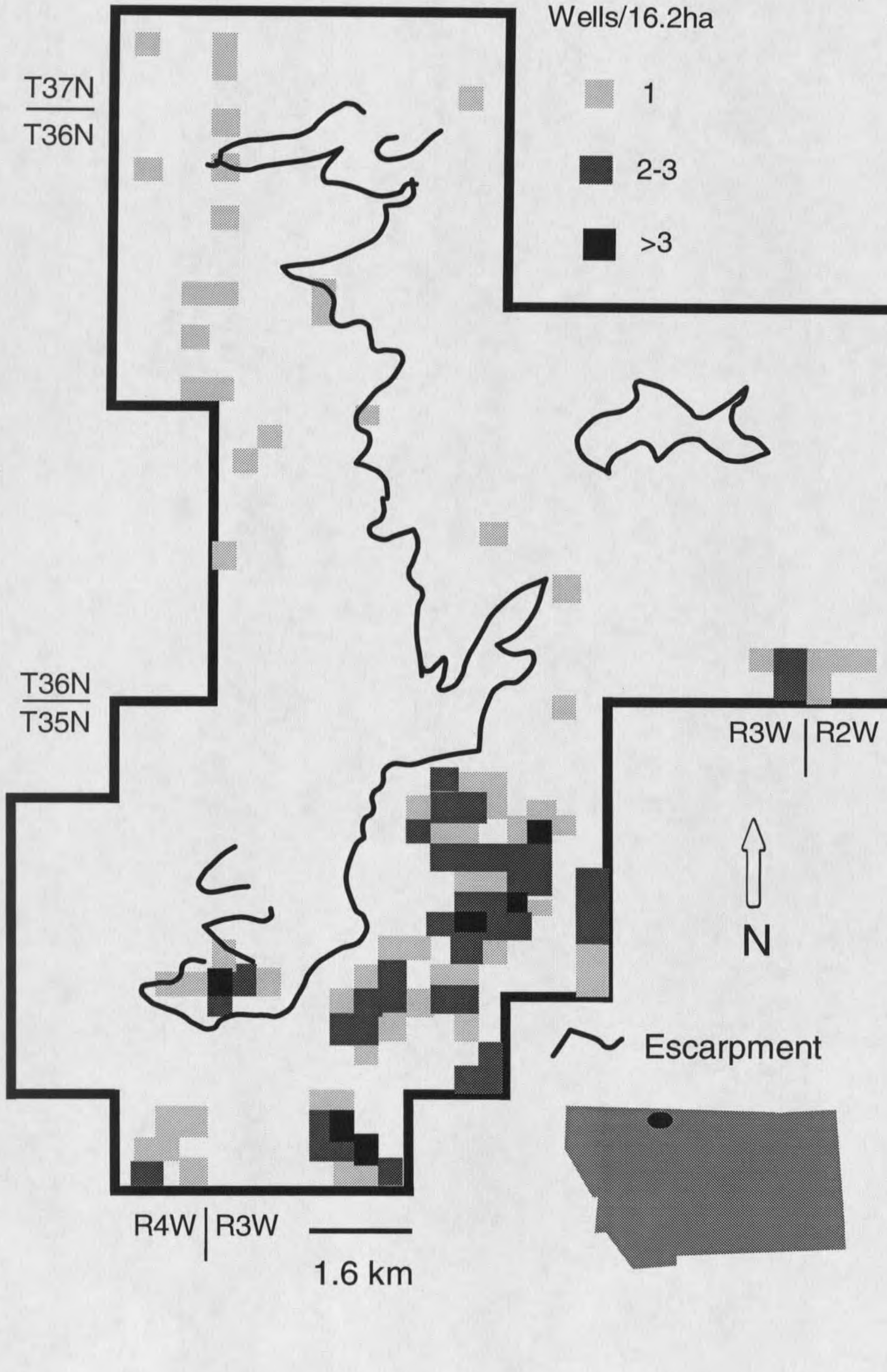

Figure 5. Locations and density of active oil and gas wells at the Kevin Rim, 1993-1994.

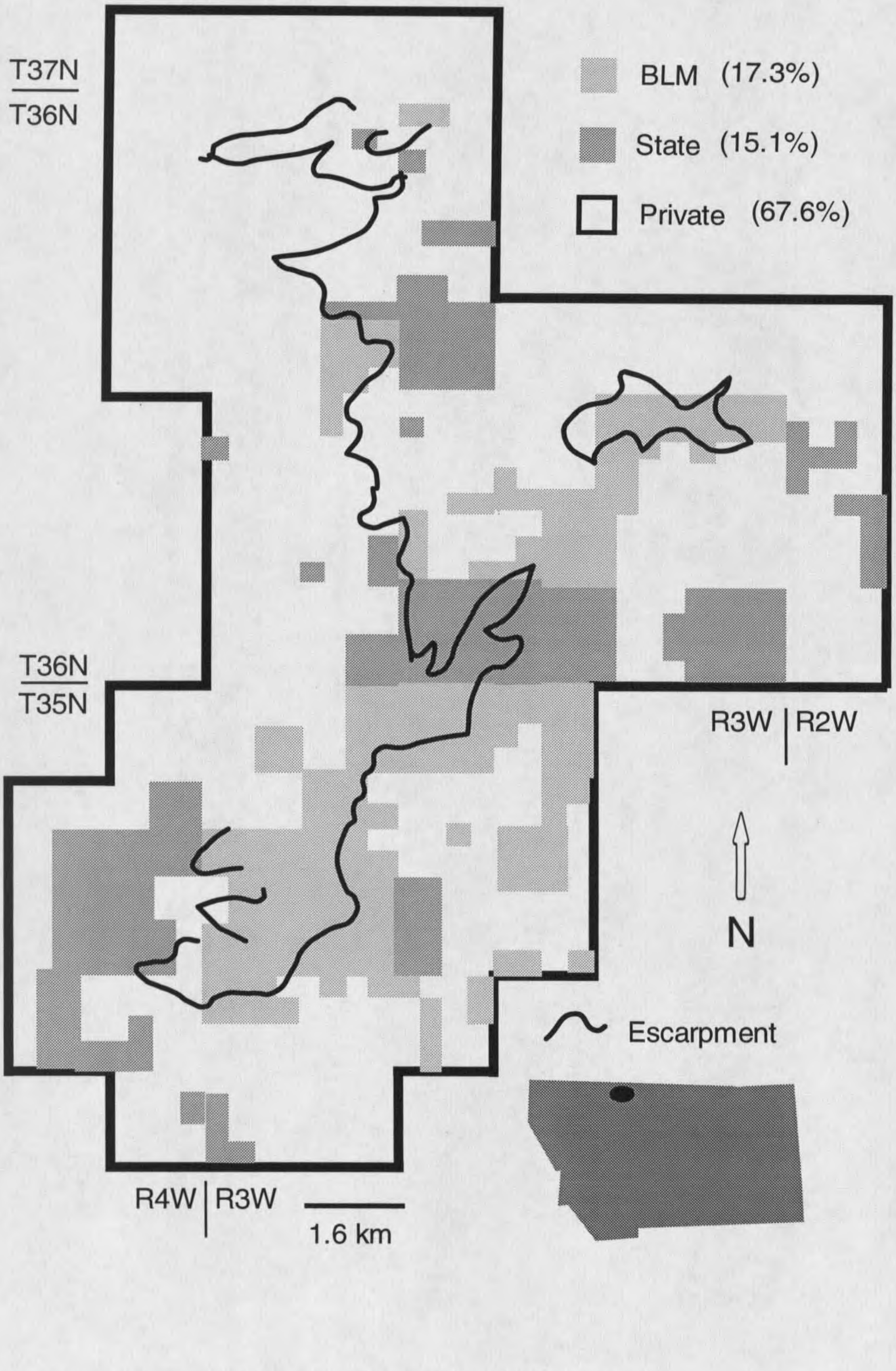

Figure 6. Land ownership at the Kevin Rim, 1993-1994.

METHODS

Data Collection

Territory Occupancy

I began searches for occupied ferruginous hawk territories on 1 April 1993 and 2 April 1994, approximately the time the birds begin establishing territories on northern breeding grounds (Lokemoen and Duebbert 1976, Blair and Schitoskey 1982, Olendorff 1993). Searches were conducted from a vehicle and on foot using 10X binoculars and a 60X spotting scope. I used locations of previously occupied nests to minimize search time in the southern portion of the study area. Suitable nesting substrates were searched in the previously unsurveyed northern portion of the study area.

To minimize the risk of researcher-caused nest abandonment, I observed nests from > 250 m during territory establishment and incubation (Snow 1974, Fyfe and Olendorff 1976, Call 1978, White and Thurow 1985). Locations of occupied nests of ferruginous hawks and all other diurnal raptors excluding northern harriers, whose nests were not located, were plotted on United States Geological Survey (USGS) 1:24,000 topographic maps (Appendix, Tables 9 and 10). Nests of great-horned owls and burrowing owls were also plotted when encountered. I recorded elevation, aspect, nest substrate, and color of adults at all occupied ferruginous hawk nests.

Nest Survival, Nestling Survival, and Productivity

I monitored all occupied ferruginous hawk nests every 2 to 5 days until they failed or fledged young. Causes of nest failure were determined when possible. All nests containing nestlings were checked within 1 to 2 days after major weather events (wind, rain, or snow storms) to determine if nest failure was weather-related. When downy young became visible from > 250 m, usually when nestlings were 7 to 10 days old (Moritsch 1985), and when weather conditions permitted, nests were approached closely to count nestlings and unhatched eggs. Nests that did not produce nestlings were also approached at this time to count unhatched eggs and to look for clues to causes of nest failure. I continued to monitor nests that produced nestlings every 2 to 3 days until failure or fledging.

Juvenile Post-fledging Survival

To monitor survival of juveniles after fledging, I attached 46 mm X 18 mm tarsus-mounted radio transmitters (L. L. Electronics, Inc., Mahomet, Ill.) to pre-fledging juveniles aged 32 to 40 days (Moritsch 1985) using leather jesses sewn with cotton thread. Jesses were designed to fall off after 2-3 months. An entire transmitter package weighed 17-20 g and included a 254-mm antenna. Radio-marked birds were also weighed and measured, and sex was determined based on weight (Howard 1975, Fyfe and Olendorff 1976, Blair 1978, Schmutz and Schmutz 1981). Radio-marked juveniles and nestmates were banded with USFWS aluminum leg bands (Appendix, Table 11).

I located radio-marked juveniles using a truck-mounted, dual 4-element null antenna system and a Telonics model T2 receiver (Telonics, Inc., Mesa, Ariz.) equipped with a null-converter box. Telemetry was used to obtain visual observations of radio-marked birds to determine their status. Radio-marked birds were located every 1 to 3 days after radio-attachment until they died, dispersed $\geq$ 5.0 km from nest sites, or until radios failed.

Habitat and Nest-site Variables

To investigate effects of factors thought to influence nest survival and productivity, I measured 20 habitat and nest-site variables for all occupied ferruginous hawk nests for evaluation in univariate and multivariate analyses. I selected variables that represented sources of habitat alteration, potential disturbance related to human activities, and competition, in addition to adult color and several characteristics of nest sites.

I plotted the locations of all cultivated fields on the study area onto USGS 1:24,000 topographic maps using farm compliance maps provided by the Toole County Consolidated Farm Service Agency (CFSA, formerly the Agricultural Stabilization and Conservation Service-ASCS), Shelby, Mont. I also plotted locations of all active oil wells using a database provided by the State Department of Natural Resources and Conservation (DNRC), Oil and Gas Conservation Division, Shelby, Mont., and I field-truthed locations of primary and secondary roads on 1:24,000 topographic maps. After plotting locations of all occupied raptor nests on topographic maps, I measured distances (m) from each occupied ferruginous hawk nest to the nearest: 1) primary road,

2) secondary road, 3) active oil well, 4) cultivated field, 5) occupied house, 6) occupied conspecific nest, and 7) occupied nest of a different raptor species larger than an American kestrel (Van Horn 1993).

In addition to measuring distances to habitat variables, I also measured the amount or intensity of habitat variables within 1.6 km of each occupied ferruginous hawk nest. On 1:24,000 topographic maps, I placed a 1.6 km-radius (8.1 km^2) circle around each occupied nest, an area that approximates the size of a ferruginous hawk home range (Lokemoen and Duebbert 1976, Olendorff 1993). I used a map measurer to determine km of primary and secondary roads, and a planimeter to calculate percent of land cultivated within 1.6 km of each nest. I also recorded numbers of active oil wells, occupied houses, and occupied nests of ferruginous hawks and other raptors within 1.6 km of each occupied nest.

Other variables recorded for each occupied ferruginous hawk nest were adult color, species of nearest nesting raptor pair, nest elevation, nest aspect, and nesting substrate. Nesting substrate was assigned based on accessibility of nests to ground predators; cliff nests were those on sheer cliff faces that were inaccessible to ground predators, outcrop nests were those elevated on blocky or irregular terrain and of intermediate accessibility to ground predators, and ground nests were those easily accessible to ground predators.

Food Habits and Prey Density

When visiting nests to count young and to attach radio transmitters, I recorded prey remains in nests. In 1994 I performed headlight surveys for lagomorphs to compare density of lagomorphs with those obtained by Harmata (1991) and Van Horn (1993). Surveys were conducted along 42.4 km of primary roads every 2 weeks between 31 May and 10 August and beginning approximately 1 hour after sunset. All lagomorphs seen with the headlights of a vehicle traveling 40 to 55 km/h were recorded. Percent cultivation on both sides of the survey route was recorded for the 12 road sections, ranging from 1.8 to 5.6 km, that comprised the survey route. In 1993 I counted active ground squirrel (S. richardsonii) burrows on randomly-located 100 m x 2 m grassland transects as an index to ground squirrel abundance (Schmutz et al. 1980). In 1994 I extended transects to include roadsides and edges of cultivated fields to compare numbers of active burrows among habitat types.

Data Analysis

Territory Occupancy

Terminology for status of ferruginous hawk breeding territories is similar to that of Postupalsky (1974). I considered territories occupied if: 1) a pair of adult hawks was consistently observed in an area containing nests or suitable nesting substrates, 2) an adult individual or pair was observed at a nest, or 3) I observed courtship/pair-bonding flights, nest-building, or nest-repair in a breeding territory. I defined active nests as those in which ≥ 1 egg was laid, productive nests were those that produced ≥ 1 nestling, and successful nests were those that fledged ≥ 1 juvenile. I tested for differences in reoccupancy in 1994 between territories and nests that were successful and those that were unsuccessful in 1993 using a chi-square test.

Nest Survival, Nestling Survival, and Productivity

To determine if nests were prone to failure at particular stages of nesting, I used the binomial method to calculate nest survival for 5 intervals during the nesting season. Intervals were: 1) occupancy to egg-laying, 2) egg-laying to hatching, 3) hatching to fledging, 4) occupancy to hatching, and 5) occupancy to fledging (nest success). Because nests were not approached closely until after hatching, exact dates and causes of failure prior to egg-laying or during incubation were not determined. If nests with young were observed to have failed within 1 to 2 days of major weather events, weather was recorded as the cause of nest failure and nestling mortality. Nests in which all young were lost in the absence of major weather events were assumed to have been depredated. If individual nestlings but not entire broods were lost in the absence of major weather events, cause of nestling mortality was classified as "other" (fratricide, starvation, or disease).

To assess productivity of the breeding population as a whole, I calculated mean numbers of eggs, nestlings, and fledglings/occupied territory. Mean clutch size, mean brood size, and mean number fledged/successful nest were calculated using active, productive, and successful nests, respectively. Number of eggs was back-calculated from the number of downy young and unhatched eggs in nests when they were visited soon after hatching (Luttich et al. 1971, Woffinden and Murphy 1977, Blair and Schitoskey 1982). Because nests were not visited during incubation, eggs lost to predation would have been missed, and estimates of egg numbers therefore represent a minimum.

Juvenile Post-fledging Survival

I calculated the finite rate of survival of radio-marked juveniles from fledging to dispersal using the binomial method (White and Garrott 1990:208). Survival was assumed to be independent among nestmates once they left the nest. Radio-marked birds were assumed to have survived the post-fledging period if they were radio-tracked and observed visually for ≥ 25 days after radio-attachment or if they dispersed > 5.0 km from their natal nest. Juveniles with failed radio transmitters were omitted from survival analysis.

Habitat and Nest-site Variables

I used both univariate and multivariate analyses to determine effects of habitat and nest-site variables on ferruginous hawk nest survival and productivity. For univariate analysis, each occupied nest was placed into 1 of 2 categories for each explanatory (habitat and nest-site) variable, and response (nest survival and productivity) variables were tested for differences between categories. Categories of explanatory variables were selected based on: 1) ferruginous hawk breeding biology, 2) potential management considerations, and 3) sample sizes necessary for valid comparisons between categories. I compared nest survival for 5 stages of the nesting season between categories of each explanatory variable using a chi-square test of the numbers of nests surviving each interval. I also compared 6 productivity parameters between categories of explanatory variables using the Mann-Whitney U-test. To balance Type I and Type II statistical errors, significance was set at 0.10 for differences in nest survival and productivity between categories of explanatory variables (Steele and Torrie 1980:88-89).

For the multivariate analysis, I used best subsets logistic regression (Hosmer and Lemeshow 1989) to test whether nest survival (0-1 response) was related to habitat and nest-site variables. I used best subsets multiple regression to test whether productivity (continuous response) was related to habitat and nest-site variables. An explanatory variable was a candidate for the best subsets regression for a response variable if the response variable differed between categories of the explanatory variable in univariate analysis ($\underline{P} \leq 0.25$; Hosmer and Lemeshow 1989:82-87).

Food Habits and Prey Density

I calculated proportions of prey species observed in nests to compare with results of previous studies. I used the Kruskal-Wallis (K-W) ANOVA to compare lagomorph density among 3 categories of roadside cultivation intensity (0%, 1-25%, and > 25%) followed by the Mann-Whitney U-test for 2 x 2 comparisons between categories when the K-W was significant ($\underline{P} < 0.05$). I tested for differences in the density of active ground squirrel burrows on 100 m x 2 m transects using the same procedure. I compared burrow density between 1993 and 1994 grassland transects, and between grassland and roadside, grassland and crop-edge, and roadside and crop-edge transects in 1994.

RESULTS

Territory Occupancy

In both 1993 and 1994 all occupied ferruginous hawk territories at the Kevin Rim were located and monitored from territory establishment in early April until dispersal of recently fledged juveniles from nest sites in mid-August. Breeding pairs were observed at nests as early as 1 April 1993 and 2 April 1994. In both years the study area supported 24 breeding pairs of ferruginous hawks; a breeding density of 7.12 km^2/pair (Fig.7). An additional 38 pairs of raptors occupied breeding territories on the study area in both years; an overall density of breeding raptors of 2.76 km^2/pair (Appendix, Tables 10 and 12). In both years, 17 of 24 breeding pairs of ferruginous hawks had 2 light phase adults, 5 pairs consisted of a dark female and a light male, and 2 pairs had a light female and a dark male (Appendix, Table 9). No breeding pairs had 2 dark adults.

Eighteen of 24 ferruginous hawk territories occupied in 1993 were reoccupied in 1994; 8 of 10 that were successful in 1993, and 10 of 14 that were unsuccessful in 1993 were reoccupied in 1994. There were no differences in rates of reoccupancy between territories that were successful and those that were unsuccessful in 1993 ($X^2 = 0.23$, df = 1, $\underline{P} = 0.63$). However, 5 of 8 territories that were successful in 1993 and reoccupied in 1994 were also successful in 1994, but only 2 of 10 territories that were unsuccessful in 1993 and reoccupied in 1994 were successful in 1994 ($X^2 = 3.38$, df = 1, $\underline{P} = 0.07$). In 14 of the 18 reoccupied territories, the same nest was used both years; 5 of 10 nests that were

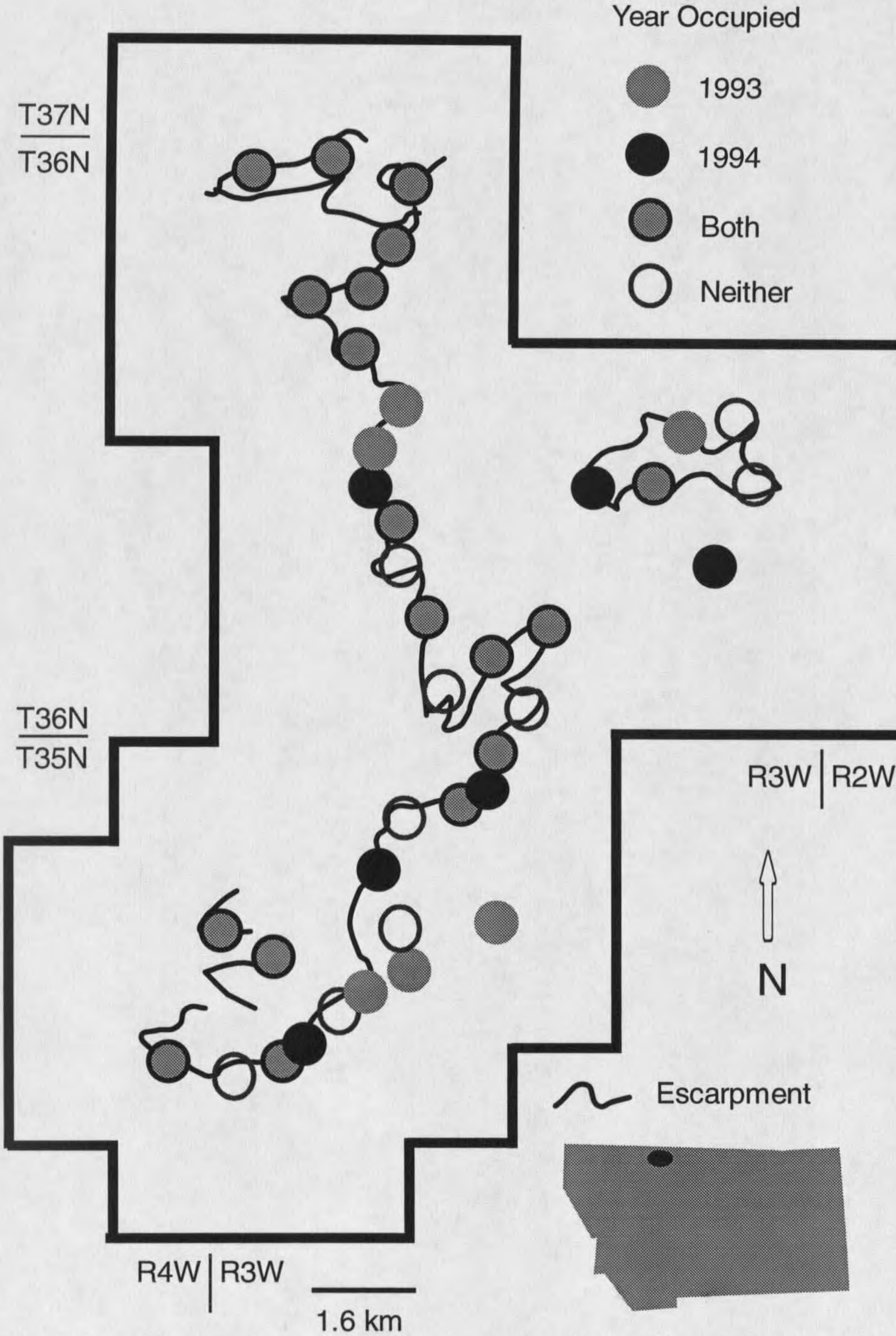

Figure 7. Locations and status of ferruginous hawk breeding territories at the Kevin Rim, 1993-1994.

successful in 1993 and 9 of 14 nests that were unsuccessful in 1993 were reoccupied in 1994. Nest reoccupancy did not differ between nests that were successful and those that were unsuccessful in 1993 ($X^2 = 0.49$, df = 1, $\underline{P} = 0.48$). However, 3 of 5 nests that were successful in 1993 and reoccupied in 1994 were successful in 1994, but only 2 of 9 nests that were unsuccessful in 1993 and reoccupied in 1994 were successful in 1994 ($X^2 = 2.00$, df = 1, $\underline{P} = 0.16$).

Nest and Nestling Survival

Nest survival did not differ between years ($\underline{P} > 0.10$) for any of the 5 nesting intervals (Table 1). For the 2 years combined, nest survival from occupancy to egg-laying was 0.75 (n = 48), from egg-laying to hatching, 0.86 (n = 36), and from hatching to fledging, 0.65 (n = 31). Nest survival was 0.65 (n = 48) from occupancy to hatching, and 0.42 (n = 48) from occupancy to fledging (nest success). Eighteen of 24 nests occupied in 1993 survived to egg-laying, 17 survived to hatching, and 10 fledged young. In 1994, 18 of 24 occupied nests survived to egg-laying, 14 survived to hatching, and 10 survived to fledging.

In 1993, 6 nests failed prior to egg-laying and another failed to hatch either of its 2 eggs. Two nests failed as a result of a severe wind, rain, and hail storm on 1 June. One nest contained 2 downy young (4-7 days old) and 1 unhatched egg, the other contained 2 very recently hatched nestlings, 1 egg that was partially hatched, and 1 unhatched egg. Five nests containing 13 young were lost to predation; 2 when young were 2-3 weeks old, and 3 when young were 3-4 weeks old. In 1994, 6 nests failed prior to egg-laying, 3 nests

Table 1. Ferruginous hawk nest survival for 5 intervals during the breeding season, 1993-1994.

Nesting Interval	Year	N	Nest Survival	SE	95% CI	P[a]
Occupancy to egg-laying	1993	24	0.75	0.09	0.56 to 0.94	
	1994	24	0.75	0.09	0.56 to 0.94	
	Both	48	0.75	0.06	0.62 to 0.88	1.00
Egg-laying to hatching	1993	18	0.94	0.06	0.83 to 1.00	
	1994	18	0.78	0.10	0.57 to 0.99	
	Both	36	0.86	0.06	0.74 to 0.98	0.15
Hatching to fledging	1993	17	0.59	0.12	0.33 to 0.85	
	1994	14	0.71	0.13	0.44 to 0.98	
	Both	31	0.65	0.09	0.47 to 0.82	0.47
Occupancy to hatching	1993	24	0.71	0.09	0.51 to 0.90	
	1994	24	0.58	0.10	0.37 to 0.80	
	Both	48	0.65	0.07	0.51 to 0.79	0.37
Occupancy to fledging	1993	24	0.42	0.10	0.20 to 0.63	
	1994	24	0.42	0.10	0.20 to 0.63	
	Both	48	0.42	0.07	0.27 to 0.56	1.00

[a] Test for difference in nest survival between years: Chi-square, df=1.

containing 7 eggs (clutches were 5, 1, and 1) failed to hatch, and 1 nest contained fragments of 2 eggs that were crushed when a rock apparently slid into the nest. Two nests containing 2 and 4 downy young, as well as a single nestling from a brood of 3, were lost to a severe wind and rain storm on 6 June. Two nests containing 2 and 4 downy young were lost to predation when young were 2-3 weeks old. A single nestling from a brood of 4 was also apparently depredated after fledging prematurely.

Nestling survival was 0.55 for the 2 years combined and did not differ between years ($X^2 = 0.04$, df = 1, $\underline{P} = 0.84$). In 1993, 24 of 43 nestlings survived to fledging. Thirteen (68.4%) nestlings were depredated, 4 (21.1%) were lost as a result of poor weather within 2 weeks of hatching, and 2 (10.5%) were lost to other causes. In 1994, 22 of 41 nestlings survived to fledging. Seven (36.8%) were depredated, 7 were lost as a result of poor weather, and 5 (26.3%) were lost to other causes.

Productivity

There were no differences between years ($\underline{P} > 0.10$) in any of the 6 productivity parameters measured (Table 2). Mean values for the 2 years combined were 2.10 eggs, 1.75 nestlings, and 0.96 young fledged/occupied territory (n = 48). Mean clutch and brood sizes were 2.81 (n = 36) and 2.71 (n = 31), respectively, and mean number of young fledged/successful nest was 2.30 (n = 20). In 1993, 24 occupied territories produced 50 eggs, 43 nestlings, and 24 fledglings. In 1994, 24 occupied territories produced 51 eggs, 41 nestlings, and 22 fledglings.

Table 2. Ferruginous hawk productivity at the Kevin Rim, 1993-1994.

Productivity parameter	Year	N	Mean	SE	95% CI	P[a]
Eggs/occupied territory	1993	24	2.08	0.28	1.51 to 2.65	
	1994	24	2.13	0.33	1.44 to 2.81	
	Both	48	2.10	0.21	1.68 to 2.53	0.87
Clutch size	1993	18	2.78	0.15	2.46 to 3.10	
	1994	18	2.83	0.28	2.24 to 3.43	
	Both	36	2.81	0.16	2.48 to 3.13	0.80
Nestlings/occupied territory	1993	24	1.79	0.27	1.24 to 2.35	
	1994	24	1.71	0.34	1.01 to 2.41	
	Both	48	1.75	0.21	1.32 to 2.18	0.90
Brood size	1993	17	2.53	0.17	2.16 to 2.90	
	1994	14	2.93	0.27	2.35 to 3.50	
	Both	31	2.71	0.16	2.39 to 3.03	0.23
No. fledged/occupied territory	1993	24	1.00	0.27	0.44 to 1.56	
	1994	24	0.92	0.26	0.38 to 1.46	
	Both	48	0.96	0.19	0.58 to 1.33	0.90
No. fledged/successful nest	1993	10	2.40	0.27	1.80 to 3.00	
	1994	10	2.20	0.33	1.46 to 2.94	
	Both	20	2.30	0.21	1.87 to 2.73	0.65

[a]Test for differences in productivity between years: Mann-Whitney U-test.

Juvenile Post-fledging Survival

I radio-marked 11 juveniles from 9 nests in 1993 and 18 juveniles from 10 nests in 1994. Three additional juveniles from a single nest 5.0 km east of the study area were radio-marked in 1994 and were included in analysis of post-fledging survival. Post-fledging survival did not differ between years ($X^2 = 0.15$, df = 1, $\underline{P} = 0.70$). For the 2 years combined, 23 of 27 radio-marked juveniles of known fate survived to disperse from the breeding area ($\hat{S} = 0.85 \pm 0.14$, SE = 0.07). Only 4 radio-marked juveniles were observed to have died, 3 within 5 days of fledging, and one approximately 10 days after fledging. Other radio-marked juveniles remained in close proximity to their natal nests for 2 to 4 weeks after fledging. Those that survived to dispersal were last observed within 5.0 km of nest sites between 4 and 6 weeks after fledging. No radio-marked juveniles were located on the study area after 15 August in either year.

In 1993, 11 radio-marked juveniles (6 males and 5 females) were monitored for 300 radio-days (mean = 27.3 days). Fates of 2 radio-marked birds were unknown due to radio failure. Of the remaining 9, 8 survived to disperse from the breeding area ($\hat{S} = 0.89 \pm 0.26$, SE = 0.11), and 1 was found dead 30 m from its natal nest 10 days after fledging. Although cause of death could not be determined, no part of the hawk appeared to have been consumed by a predator. In 1994, 21 radio-marked juveniles (9 males and 12 females) were monitored for 608 radio-days (mean = 29.0 days). Fates of 3 juveniles were unknown due to radio failure. Of the remaining 18, 15 survived to disperse from the breeding area ($\hat{S} = 0.83 \pm 0.19$, SE = 0.09), and 3 radio-marked juveniles from a single nest were found dead on the same day within 150 m of their natal nest and within 5 days of fledging. All 3 suffered large wounds to the top of the cranium, consistent with those attributed to great-horned owls (Luttich et al. 1971), but no part of any of the 3 hawks had been consumed. However, 1 of the dead birds was found pulled head-first partially into a small burrow, probably that of a long-tailed weasel (Mustela frenata).

Habitat and Nest-site Variables

Nineteen (55.9%) of 34 different nests occupied during the study were cliff nests, 9 (26.5%) were ground nests, 5 (14.7%) were on rock outcrops, and 1 was on top of a grain bin. Twenty-two (66.7%) of 33 different occupied nests had aspects between 135^{O} (SE) and 225^{O} (SW) , 6 (18.2%) had easterly aspects, 4 (12.1%) had westerly aspects, and 1 had a northerly aspect. Twenty-four (50.0%) of 48 breeding pairs of ferruginous hawks had prairie falcons as the nearest nesting raptor pair, 12 (25.0%) were closest to another pair of ferruginous hawks, 4 (8.3%) were closest to a pair of red-tailed hawks, 4 were closest to a pair of great-horned owls, 2 (4.2%) were closest to a pair of golden eagles, and 2 were closest to a pair of Swainson's hawks.

Eighteen habitat and nest-site variables were included in analysis of ferruginous hawk nest survival and productivity (Table 3). Distance to nearest house and number of houses within 1.6 km of occupied nests were dropped from analysis because only 1 nest, occupied both years, was within 1.6 km of an occupied house. Univariate and multivariate analyses indicated that ferruginous hawk nest survival and productivity were related to proximity of nests to cultivated fields, active oil wells, secondary roads, and other

Table 3. Habitat and nest-site variables of occupied ferruginous hawk nests at the Kevin Rim, 1993-1994, and categories used in univariate analysis of factors affecting nest survival and productivity.

Variable	N[a]	Mean	SE	Minimum	Maximum	Univariate Categories[b] 1(n)	2(n)
Nest elevation (m)	34	1,189.8	8.0	1,067	1,268	<1200m (30)	>1200m (18)
Nest aspect (°)	33	170.2	10.0	41	296	135°-225° (33)	225°-135° (14)
Nest substrate	34					cliff (29)	other (19)
Adult color	48					both light (34)	1 dark (14)
Nearest nesting raptor species	48					*B. regalis* (12)	other (36)
Distance (m) to nearest:							
Primary road	34	2,680.7	240.4	255	5,724	<1600m (12)	>1600m (36)
Secondary road	34	377.0	35.6	21	908	<400m (29)	>400m (19)
Active oil well	34	3,943.3	594.5	122	10,816	<1600m (19)	>1600m (29)
Cultivated field	34	1,148.6	129.4	31	2,449	<800m (17)	>800m (31)
Conspecific nest	48	942.7	80.5	143	3,316	<800m (23)	>800m (25)
Other raptor nest	48	614.6	87.5	0[c]	3,316	<400m (18)	>400m (30)

[a]Sample sizes do not include reoccupied nests for variables that were constant between years.
[b]Sample sizes include nests occupied both years.
[c]A pair of ferruginous hawks attempted to use a nest located directly over a great-horned owl cliff eyrie.

Table 3. Continued.

Variable	N[a]	Mean	SE	Minimum	Maximum	Univariate Categories[b]	
						1(n)	2(n)
Amount within 1.6 km of nest:							
Km primary road	34	0.7	0.2	0	4.9	0 km (36)	>0 km (12)
Km secondary road	34	10.7	0.7	4.6	23.9	<10 km (27)	>10 km (21)
No. active oil wells	34	7.2	2.2	0	63	0 (29)	≥ 1 (19)
Percent cultivation	34	12.9	2.9	0	57.6	<10% (30)	>10% (18)
No. conspecific nests	48	1.7	0.1	0	4	≤ 1 (21)	≥ 2 (27)
No. nests other raptor species	48	4.4	0.4	0	11	≤ 4 (28)	≥ 5 (20)
Total no. raptor nests	48	6.1	0.5	0	13	≤ 6 (25)	≥ 7 (23)

[a]Sample sizes do not include reoccupied nests for variables that were constant between years.
[b]Sample sizes include nests occupied both years.

breeding raptors, as well as to the number/intensity of these variables within 1.6 km of occupied nests.

Analyses of factors thought to influence ferruginous hawk nest survival and productivity were exploratory in that no experimental controls were used and factors could not be randomly applied to nests. Rather, natural variation in habitat and nest-site features were quantified and compared in an attempt to develop hypotheses regarding factors important in determining ferruginous hawk breeding success. Also, because of sample size limitations, only relatively large differences in nest survival and productivity between categories of explanatory variables could be detected. For example, differences in nest survival for various intervals had to be 0.17 to 0.24 between categories of explanatory variables to be statistically significant ($\underline{P} < 0.10$). Even larger differences (0.30 to 0.45) were required to attain adequate statistical power (> 0.80). Similarly, productivity parameters had to differ by 0.53 to 0.73 between categories to be statistically significant and by approximately 1 egg, nestling, or fledgling for adequate statistical power (Borenstein and Cohen 1988). The low power to detect small differences in nest survival and productivity, which may be important to ferruginous hawk breeding success, should be considered when interpreting results of statistical tests of differences in these parameters between categories of habitat and nest-site variables.

Univariate Analysis

Nest survival during various intervals differed significantly ($\underline{P} < 0.10$) between nests with different habitat characteristics (Table 4). Nests with > 10% cultivated land within 1.6 km had higher nest survival from occupancy to egg-laying than nests with

Table 4. Habitat and nest-site variables that were related to ferruginous hawk nest survival at the Kevin Rim, 1993-1994.

Nesting interval	Explanatory variable	Category 1	N	Mean Survival	Category 2	N	Mean Survival	P[a]
Occupancy to egg-laying	Percent cultivation within 1.6 km	<10 %	30	0.67	>10%	18	0.89	0.09
Egg-laying to hatching	Distance to oil well	<1600m	12	1.00	>1600m	24	0.79	0.09
	Number oil wells	0	24	0.79	≥ 1	12	1.00	0.09
	Km secondary roads	<10km	21	0.76	>10km	15	1.00	0.04
Hatching to fledging	Distance to oil well	<1600m	12	0.83	>1600m	19	0.53	0.08
	Distance to conspecific nest	<800m	15	0.47	>800m	16	0.81	0.04
	Km secondary roads	<10km	16	0.44	>10km	15	0.87	0.01
	Number oil wells	0	19	0.53	≥ 1	12	0.83	0.08
Occupancy to hatching	No differences detected.							
Occupancy to fledging	Km secondary roads	<10km	27	0.26	>10km	21	0.62	0.01

[a] Test for differences between categories: Chi-square, df=1.

< 10% cultivated land within 1.6 km. Nests with > 10 km of secondary roads within 1.6 km had higher nest survival from egg-laying to hatching, from hatching to fledging, and from occupancy to fledging (nest success) than nests with < 10 km of secondary roads within 1.6 km. Nests with ≥ 1 active oil well within 1.6 km had higher nest survival from egg-laying to hatching and from hatching to fledging than nests with no active oil wells within 1.6 km. Nests > 800 m from an occupied conspecific nest had higher nest survival from hatching to fledging than nests within 800 m of an occupied conspecific nest.

Several productivity parameters also differed significantly ($\underline{P} < 0.10$) between categories of explanatory variables (Table 5). Nests with > 10% cultivated land within 1.6 km produced more eggs and nestlings/occupied territory, had larger clutch and brood sizes, and fledged more young/successful nest than nests with < 10% cultivated land within 1.6 km. Similarly, nests within 800 m of a cultivated field produced more eggs/ occupied territory, had larger clutch and brood sizes, and fledged more young/successful nest than nests > 800 m from the nearest cultivated field. Nests with > 10 km of secondary roads within 1.6 km fledged more young/occupied territory than nests with < 10 km of secondary roads within 1.6 km. Nests > 800 m from another occupied ferruginous hawk nest had larger clutch size than nests within 800 m of an occupied conspecific nest. Similarly, nests with ≤ 1 occupied conspecific nest, ≤ 4 occupied nests of other raptor species, or ≤ 6 total occupied raptor nests within 1.6 km had larger brood sizes than nests with ≥ 2 occupied conspecific nests, ≥ 5 occupied nests of other raptor

Table 5. Habitat and nest-site variables that were related to ferruginous hawk productivity at the Kevin Rim, 1993-1994.

Productivity parameter	Explanatory variable	Category 1	N	Mean	Category 2	N	Mean	P[a]
Eggs/occupied territory	Distance to crop field	<800m	17	2.71	>800m	31	1.77	0.03
	Percent cultivation	<10%	30	1.63	>10%	18	2.89	0.003
Clutch size	Distance to crop field	<800m	14	3.29	>800m	22	2.50	0.02
	Percent cultivation	<10%	20	2.45	>10%	16	3.25	0.01
	Distance to ferruginous hawk nest	<800m	17	2.41	>800m	19	3.16	0.02
Nestlings/occupied territory	Percent cultivation	<10%	30	1.37	>10%	18	2.39	0.03
Brood size	Distance to crop field	<800m	12	3.08	>800m	19	2.47	0.08
	Percent cultivation	<10%	17	2.41	>10%	14	3.07	0.06
	Number ferruginous hawk nests	≤ 1	13	3.08	≥ 2	18	2.44	0.06
	Number other raptor nests	≤ 4	17	3.00	≥ 5	14	2.36	0.05
	Total number raptor nests	≤ 6	15	3.00	≥ 7	16	2.44	0.08
Fledged/occupied territory	Km secondary roads	<10km	27	0.74	>10km	21	1.24	0.10
Fledged/successful nest	Elevation	<1200m	11	2.64	>1200m	9	1.89	0.09
	Distance to crop field	<800m	8	2.75	>800	12	2.00	0.08
	Percent cultivation	<10%	11	1.82	>10%	9	2.86	0.02
	Km secondary roads	<10km	7	2.86	>10km	13	2.00	0.08

[a] Test for differences between categories: Mann-Whitney U-test.

species, or ≥ 7 total occupied raptor nests within 1.6 km. Nests with elevations below 1200 m fledged more young/successful nest than nests above 1200 m.

Multivariate Analysis

Regression analyses produced several models that explained a significant amount of variation in ferruginous hawk nest survival and productivity (Tables 6 and 7). However, none of the models explained > 29% of the variation in any of these parameters. Nest survival from hatching to fledging was positively related to the number of km of secondary roads within 1.6 km of occupied nests (C_p = 0.26, Adj. R^2 = 0.06, $\underline{P}$ = 0.09). The best subsets routine failed to produce models that explained a significant amount of variation in nest survival over the remaining intervals.

The number of eggs/occupied territory was positively related to distance of nests from the nearest active oil well and to number of active oil wells and percent cultivation within 1.6 km of nests (C_p = 2.75, Adj. R^2 = 0.17, $\underline{P}$ = 0.01). Clutch size (C_p = 0.08, Adj. R^2 = 0.17, $\underline{P}$ = 0.02) and brood size (C_p = 1.79, Adj. R^2 = 0.27, $\underline{P}$ = 0.005) were positively related to percent cultivation and negatively related to the total number of occupied raptor nests within 1.6 km of occupied ferruginous hawk nests. The number of young fledged/successful nest was also positively related to percent cultivation within 1.6 km of occupied nests (C_p = -2.23, Adj. R^2 = 0.29, $\underline{P}$ = 0.009). The best subsets routine failed to produce models that explained a significant amount of the variation in number of nestlings/occupied territory or number of young fledged/occupied territory.

Table 6. Results of best subsets logistic regression of factors related to ferruginous hawk nest survival at the Kevin Rim, 1993-1994.

Nesting interval	Model intercepts and coefficients	C_p	Adj. R^2	F	P	DF
Occupancy to Egg-laying[a]	$S^f = 0.74 + 0.03(\text{PERCUL})^g$	2.29	0.0071	1.336	0.2538	1
Egg-laying to hatching[b]	Logistic regression failed to converge.					
Hatching to fledging[c]	S = -2.80 + 0.34(KMRD2)	0.26	0.0636	3.037	0.0920	1
Occupancy to hatching[d]	S = 0.39 + 0.01(PERCUL)	3.50	-0.0128	0.404	0.5281	1
Occupancy to fledging[e]	S = -0.99 + 0.0007(DISFH)	0.92	0.0034	1.160	0.2871	1

[a]DISOIL (P = 0.13), NUMOIL (P = 0.13), PERCUL (P = 0.09), and NUMFH (P = 0.24) were allowed entry to the regression.

[b]DISOIL (P = 0.09), NUMOIL (P = 0.09), and KMRD2 (P = 0.04) were allowed entry to the regression.

[c]ELEV (P = 0.14), DISRD2 (P = 0.18), DISOIL (P = 0.08), DISFH (P = 0.04), KMRD2 (P = 0.01), and NUMOIL (P = 0.08) were allowed entry to the regression.

[d]Only PERCUL (P = 0.14) was allowed entry to the regression.

[e]DISOIL (P = 0.21), DISFH (P = 0.13), KMRD2 (P = 0.01), and NUMOIL (P = 0.21) were allowed entry to the regression.

[f]S = nest survival.

[g]PERCUL = percent cultivated land within 1.6 km of occupied ferruginous-hawk nests.
KMRD2 = number of km of secondary roads within 1.6 km of occupied ferruginous-hawk nests.
DISFH = distance (m) to nearest occupied conspecific nest.
DISOIL = distance (m) to nearest active oil well.
NUMOIL = number of active oil wells within 1.6 km of occupied ferruginous-hawk nests.
NUMFH = number of occupied nests of conspecifics within 1.6 km of occupied ferruginous-hawk nests.
ELEV = nest elevation (m).
DISRD2 = distance (m) to nearest secondary road.

Table 7. Results of best subsets multiple regression of factors related to ferruginous hawk productivity at the Kevin Rim, 1993-1994.

Productivity parameter	Model intercepts and coefficients	C_p	Adj. R^2	F	P	DF
Eggs/occupied territory[a]	2.54 - 0.0002(DISOIL)[g] - 0.04(NUMOIL) + 0.04(PERCUL)	2.75	0.1711	4.233	0.0103	3
Clutch size[b]	3.14 + 0.02(PERCUL) - 0.09(NUMRAP)	0.08	0.1689	4.557	0.0179	2
Nestlings/occupied territory[c]	2.26 - 0.0005(DISCUL)	1.01	0.0304	2.475	0.1225	1
Brood size[d]	3.38 + 0.01(PERCUL) - 0.13(NUMRAP)	1.79	0.2716	6.592	0.0045	2
No. fledged/occupied territory[e]	1.41 - 0.001(DISRD2)	0.60	0.0221	2.060	0.1580	1
No. fledged/successful nest[f]	1.85 + 0.03(PERCUL)	-2.23	0.2875	8.666	0.0087	1

[a]DISOIL (P = 0.11), DISCUL (P = 0.03), DISFH (P = 0.10), NUMOIL (P = 0.11), and PERCUL (P = 0.003) were allowed entry to the regression.

[b]DISCUL (P = 0.02), DISFH (P = 0.02), PERCUL (P = 0.01), NUMFH (P = 0.12), and NUMRAP (P = 0.25) were allowed entry to the regression.

[c]DISCUL (P = 0.14), and PERCUL (P = 0.03) were allowed entry to the regression.

[d]DISCUL (P = 0.08), DISFH (P = 0.12), PERCUL (P = 0.06), NUMFH (P = 0.06), NUMOTH (P = 0.05), and NUMRAP (P = 0.08) were allowed entry to the regression.

[e]DISRD2 (P = 0.23), DISFH (P = 0.19), KMRD2 (P = 0.10), and PERCUL (P = 0.15) were allowed entry to the regression.

[f]ELEV (P = 0.09), DISOIL (P = 0.20), DISCUL (P = 0.08), KMRD2 (P = 0.08), NUMOIL (P = 0.20), PERCUL (P = 0.02), and NUMFH (P = 0.15) were allowed entry to the regression.

[g]DISOIL = distance (m) to nearest active oil well.
DISCUL = distance (m) to nearest cultivated field.
DISRD2 = distance (m) to nearest secondary road.
DISFH = distance (m) to nearest occupied nest of a conspecific.
NUMOIL = number of active oil wells within 1.6 km of occupied ferruginous-hawk nests.
PERCUL = percent cultivated land within 1.6 km of occupied ferruginous-hawk nests.
NUMRAP = total number of occupied raptor nests within 1.6 km of occupied ferruginous-hawk nests.
NUMFH = number of occupied nests of conspecifics within 1.6 km of occupied ferruginous-hawk nests.
KMRD2 = number of km of secondary roads within 1.6 km of occupied ferruginous-hawk nests.
ELEV = nest elevation (m).

Food Habits and Prey Density

During 30 visits to ferruginous hawk nests in which prey remains in the nest bowl were counted, I recorded 25 prey items: 20 ground squirrels (S. richardsonii), 2 desert cottontails (Sylvilagus audubonii), 1 white-tailed jackrabbit (L. townsendii), 1 unidentified duck, and 1 unidentified passerine. Smaller prey items, which are less visible in nests with young and probably do not remain in nests as long as larger prey items (Schmutz 1977), may have gone undetected.

I recorded 14 lagomorphs during 6 headlight surveys, each of which covered 42.4 km (0.06 lagomorphs/km). Four survey roads (13.8 km) had 0% cultivation on either side of the road and a mean lagomorph density of 0.02/km. Five survey roads (17.4 km) had cultivation intensities between 1 and 25% and a mean lagomorph density of 0.06/km. Three survey roads (11.2 km) had cultivation intensities > 25% and a mean lagomorph density of 0.09/km. There were no differences in lagomorph density between survey roads with 0% cultivation and those with 1-25% cultivation (Mann-Whitney U-test, Z = -0.49, $\underline{P}$ = 0.62), or between survey roads with 1-25% cultivation and those with > 25% cultivation (Mann-Whitney U-test, Z = -1.34, $\underline{P}$ = 0.18). However, lagomorph density was significantly higher on survey roads with > 25% cultivation than on those with 0% cultivation (Mann-Whitney U-test, Z = -2.12, $\underline{P}$ = 0.03).

The density of active ground squirrel burrows on 100 m x 2 m transects differed considerably between grasslands, roadsides, and edges of cultivated fields. There was no difference in burrow density between 1993 and 1994 grassland transects (Mann-Whitney

U-test, Z = -0.81, P = 0.42). Burrow density was significantly greater on roadside transects than on grassland transects (Mann-Whitney U-test, Z = -2.82, P < 0.005). Burrow density on crop-edge transects was significantly greater than those on both grassland (Mann-Whitney U-test, Z = -6.54, P < 0.0001) and roadside (Mann-Whitney U-test, Z = -4.39, P < 0.0001) transects (Table 8).

Table 8. Density of active ground squirrel (Spermophilus richardsonii) burrows on 100 m x 2 m transects at the Kevin Rim, 1993-1994.

Habitat	Number of transects	Burrow Density (mean no./transect)	SE	95% CI
Grassland (1993)	21	2.10 A[a]	0.44	1.19 to 3.00
Grassland (1994)	60	1.82 A	0.28	1.27 to 2.37
Roadside (1994)	30	3.57 B	0.56	2.41 to 4.72
Crop-edge (1994)	30	10.03 C	1.16	7.66 to 12.41

[a]Different capital letters indicate significant differences in burrow density (Mann-Whitney U-test, P < 0.005).

DISCUSSION

Territory Occupancy

The breeding density of ferruginous hawks at the Kevin Rim in 1993 and 1994 (7.12 km^2/pair) was again among the highest reported for the species and confirmed the Rim as an important breeding areas for ferruginous hawks in Montana. Breeding densities of ferruginous hawks have ranged from 7.1 km^2/pair in Saskatchewan to 4,261.0 km^2/pair in Washington (Olendorff 1993). In areas containing > 20 pairs, densities have ranged from 9.8 km^2/pair in Oregon to 879.2 km^2/pair in Kansas (Olendorff 1993). In Montana, reported breeding densities are: 37.8 to 44.7 km^2/pair in the southeast (Ensign 1983, Wittenhagen 1992), 81.9 km^2/pair in the northeast (Black 1992), and 15.7 to 21.3 km^2/pair in the southwest part of the state (Meyers 1987; Restani 1989, 1991).

DuBois (1988) attributed the high density of breeding raptors at the Kevin Rim to an abundant prey base of Richardson's ground squirrels and white-tailed jackrabbits. Similarly, Harmata (1991) related ferruginous hawk breeding success to a nest's proximity to concentrations of ground squirrels. Although exact study-area locations have differed among research efforts conducted at the Kevin Rim, a 119.2 km^2 area encompassing approximately the southern two-thirds of the Rim and an adjacent area of badlands to the east has been consistently surveyed for breeding ferruginous hawks. Breeding densities on this common area ranged from 5.18 to 7.94 km^2/pair and exhibited a downward trend between 1988 and 1994 (Zelenak and Rotella 1994, this study). Because levels of oil development and agricultural activity apparently did not change greatly during this span, I speculate that the decrease in breeding density is attributable to other factors, the most likely of which is declining prey numbers.

Several researchers have reported changes in ferruginous hawk breeding densities concurrent with changes in prey populations (Smith et al. 1981, Houston and Bechard 1984, Schmutz and Hungle 1989). Howard and Wolfe (1976) suspected that an increase in area/successful nest among breeding ferruginous hawks in northern Utah and southeastern Idaho reflected changes in the territorial requirements of breeding pairs relative to abundance of prey. Similarly, Woffinden and Murphy (1977, 1983) reported increased distances between occupied nests in response to declining jackrabbit numbers. Gilmer and Stewart (1983) and Schmutz (1987b) concluded that breeding densities of ferruginous hawks were dependent on abundance and availability of ground squirrels.

Except for data from the current study, which showed no difference in density of ground squirrel burrows between 1993 and 1994 grassland transects, there are no data for comparing ground squirrel abundance among years at the Kevin Rim. However, headlight surveys of lagomorphs, performed at the Rim from 1990 to 1992 and again in 1994 have shown a steady decline in lagomorph density during this span. DuBois (1988) described white-tailed jackrabbits as abundant at the Kevin Rim. In 1990, Harmata (1991) recorded 0.56 lagomorphs/km of survey route, however, no jackrabbits were recorded in analysis of ferruginous hawk prey items. Jackrabbit density declined to 0.19 and 0.09/km in 1991 and 1992, respectively (Van Horn 1993), and 0.06/km in 1994. Thus, although lagomorphs were not the primary prey of ferruginous hawks at the Kevin Rim, the decline in numbers of breeding pairs between 1988 and 1994 may be a response to a decrease in lagomorph abundance. It is not known if ground squirrel numbers also declined at the Rim during this time.

Nest and Nestling Survival

During the 1993 and 1994 breeding seasons at the Kevin Rim, 75% of occupied ferruginous hawk nests survived to produce eggs, 65% produced nestlings, and 42% fledged young. Nests were most prone to failure during the interval between hatching and fledging, when 35% of nests with nestlings failed as a result of predation (64%) or unfavorable weather (36%).

Wittenhagen (1992) reported that 92% of occupied ferruginous hawk nests (n = 47) on 3 areas in southeastern Montana produced eggs, 72% produced nestlings, and 66% fledged young. In the same area, Ensign (1983) reported that 17% and 27% of breeding pairs failed to lay eggs in 1981 and 1982, respectively, and that only 26% of nests fledged young. In southwestern Montana, Restani (1989) reported that 80% of occupied nests produced eggs and 67% fledged young. In Utah, Weston (1969) reported that 38.5% and 7.1% of breeding pairs failed to lay eggs in 1967 and 1968, respectively. Luttich et al. (1971), and Johnson (1975) reported that 14% and 12% of breeding red-tailed hawks failed to produce eggs in Alberta and southwest Montana, respectively.

Although ferruginous hawk nest survival for all stages of the nesting season has not been widely documented, several researchers have reported nest success (the proportion of occupied nests that fledged ≥ 1 young). Howard and Wolfe (1976) reported 83% nest success in a breeding population in northern Utah and southeastern Idaho. Blair and Schitoskey (1982) reported 72% and 82% nest success in 1976 and 1977, respectively, for a breeding population in South Dakota. Gilmer and Stewart (1983) reported nest success in North Dakota ranging from 64% in 1977 to 76% in 1979. Nest success among red-tailed hawks ranged from 50% to 81% (Gates 1972, Johnson 1975, Mader 1978).

Ferruginous hawk nest success in Montana ranged from 26% (Ensign 1983) to 85% (Wittenhagen 1992) in the southeast, and from 33% (Atkinson 1993) to 67% (Restani 1989) in the southwest part of the state. Van Horn (1993) reported nest success at the Kevin Rim as 57% and 40% in 1991 and 1992, respectively. Thus, nest success at the Rim in 1993 and 1994 (42%) was similar to that reported for 1992 (Van Horn 1993) but lower than rates reported for most other areas.

Only 1 nest appeared to have failed as a result of human disturbance related to oil-field activities. Overall, however, levels of human disturbance at the Kevin Rim remained relatively low (Harmata 1991, Van Horn 1993, this study) and appeared not to be a major factor related to ferruginous hawk nest failure. In fact, failure of nests prior to egg-laying in areas with no oil wells and with no observed incidences of human-related disturbance indicate that nest failure is probably related to other factors. Number of breeding pairs of ferruginous hawks that produce eggs, number of eggs laid, and number of young produced have all been related to prey abundance (Smith and Murphy 1978, 1979; Smith et al. 1981; Schmutz and Hungle 1989; Woffinden and Murphy 1989; Olendorff 1993). The decline in lagomorph density between 1990 and 1994 described above may be related to failure of breeding pairs at the Kevin Rim to produce eggs.

Overall nestling mortality at the Kevin Rim in 1993 and 1994 was 45%. Predation and weather were responsible for 53% and 29% of nestling losses, respectively. Eighteen percent of nestling losses were due to other causes (fratricide, starvation, or disease). Predators responsible for ferruginous hawk nestling mortalities were not determined, however, great-horned owls and golden eagles also nested on the study area, and coyotes (Canis latrans), red foxes (Vulpes vulpes), and badgers (Taxidea taxus) were also observed. Van Horn (1993) also reported predation and weather as the major causes of nest loss and nestling mortality at the Kevin Rim, accounting for 51% and 37% of nestling losses, respectively. He attributed predation of some nestlings to great-horned owls and coyotes. Gilmer and Stewart (1983) reported that summer storms and predators were responsible for 37% and 15% of nest losses, respectively, on their North Dakota study area. Ensign (1983) reported 69% nestling mortality in southeastern Montana, and Weston (1969) reported 0% and 15% nestling mortality in Utah in 1967 and 1968, respectively. Luttich et al. (1971) reported nestling mortality as 27% for red-tailed hawks in Alberta.

Productivity

Productivity of ferruginous hawks at the Kevin Rim in 1993 and 1994 was lower than that reported for most other areas, although not all productivity parameters could be compared among studies. Of 29 studies for which mean clutch size was reported, 18 reported clutch sizes larger than the 1993-1994 average (2.81) at the Kevin Rim, 4 reported similar clutch sizes, and 7 reported smaller mean clutch sizes (Olendorff 1993). Wittenhagen (1992) reported mean clutch sizes of 3.0 and 3.3 in southeastern Montana in 1991 and 1992, respectively. Mean brood sizes at the Kevin Rim in 1993 (2.53) and 1994 (2.93) were similar to those reported by Van Horn (1993) for 1991 (2.50) and 1992 (2.80).

The mean number of young fledged/occupied nest at the Kevin Rim in 1993 and 1994 (0.96) was lower than that reported in 26 of 29 studies summarized by Van Horn (1993). It was also lower than the minimum value of 2.00 young fledged/occupied nest derived from DuBois' (1988) data. Harmata (1991) reported 2.60 and 0.08 young fledged/occupied nest on the KRSA (experimental) and Badlands/Buckley Coulee (control) areas, respectively. Van Horn (1993) reported 1.50 and 0.80 young fledged/ occupied nest at the Kevin Rim in 1991 and 1992, respectively.

As with breeding density and the number of pairs that lay eggs, clutch and brood sizes and the number of young fledged have been closely linked to prey abundance and availability (Howard and Wolfe 1976, Smith et al. 1981, Gilmer and Stewart 1983, Houston and Bechard 1984, Schmutz and Hungle 1989, Woffinden and Murphy 1989, Olendorff 1993). Decreased productivity at the Kevin Rim from 1988 to 1994 (Zelenak and Rotella 1994, this study) is probably a reflection of declining prey numbers and may be related to the decrease in lagomorph abundance.

Juvenile Post-fledging Survival

Survival of juveniles from fledging until dispersal from breeding areas is critical in estimating actual reproductive success and serves as another measure of the quality of a particular breeding area. The post-fledging survival rate of 0.85 among radio-marked juveniles at the Kevin Rim in 1993 and 1994 implies that most hawks that reached fledging age survived to disperse from the breeding area.

Based on a total of 14 juvenile ferruginous hawks that have been radio-marked in 5 other studies, post-fledging, pre-dispersal survival appears to also be high in other breeding areas. Blair and Schitoskey (1982) reported that all 6 radio-marked juveniles on their South Dakota study area dispersed from the breeding area during the fifth week after fledging. Two juveniles radio-marked by Ensign (1983) in southeastern Montana survived to disperse from breeding sites, which they vacated 4.5 weeks after fledging. Similarly, 2 juveniles radio-marked in Utah survived to dispersal; they left nest areas 20 to 30 days after fledging (Woffinden and Murphy 1983). Two of 3 radio-marked juveniles in southwest Montana apparently survived to dispersal, and 1 was found dead from starvation (Restani 1989). At the Kevin Rim in 1990, 1 radio-marked juvenile dispersed from the breeding area by mid-August (Harmata 1991). Konrad and Gilmer (1986) reported that 16 (89%) of 18 color-marked juveniles in North Dakota survived to disperse from nest sites, and they reported a mean post-fledging period of 23.2 days.

Habitat and Nest-site Variables

Low levels of cultivation appeared to positively influence nest survival and productivity of ferruginous hawks at the Kevin Rim. However, only 20% of the study area was cultivated, only 11 occupied nests had cultivation intensities > 30%, and only 1 nest, occupied both years, had a cultivation intensity > 50%. From this sample I was unable to determine if there was a threshold cultivation intensity above which nest survival and productivity would be negatively influenced.

The relatively higher nest survival and productivity of ferruginous hawk nests near cultivated fields and those with greater cultivation intensity in the nest vicinity appeared to be a response to greater prey abundance in such areas. The number of active ground squirrel burrows counted on crop-edge transects was nearly 5 times greater than the number counted on grassland transects. Schmutz (1987b, 1989) documented an increase in a southeastern Alberta ferruginous hawk population and reported that the primary increase in breeding pairs occurred in areas with cultivation intensities < 50%. He reported that areas of extensive cultivation were avoided by ferruginous hawks and that breeding population size appeared to be limited by degree of cultivation (Schmutz 1987b). He also reported, however, that breeding density was higher in areas of moderate (< 30%) cultivation than in uncultivated grasslands (Schmutz 1989), and that ground squirrels occurred at unusually high densities near agricultural fields (Schmutz 1977, 1987b).

Many researchers have reported the negative impacts of agriculture on breeding densities and productivity of ferruginous hawks (Olendorff and Stoddart 1974; Schmutz

1984, 1987a; Olendorff et al. 1989, Olendorff 1993). Howard and Wolfe (1976) speculated that conversion of native vegetation to monotypic stands could reduce ferruginous hawk breeding densities and reproductive success due to increased disturbance, loss of nesting sites, and reduction of major prey populations. They also reported that cultivated areas on their northern Utah-southern Idaho study area contained no ferruginous hawk nests (Howard and Wolfe 1976). In North Dakota, only 1.3% of ferruginous hawk nests were located in areas with high (> 82%) levels of cultivation and few nests occurred where > 50% of the land was cultivated (Gilmer and Stewart 1983). These authors also speculated that intensive agriculture reduced the capacity of some areas to support critical prey populations (Gilmer and Stewart 1983). Blair and Schitoskey (1982) likewise reported that areas dominated by small-grain farming were unsuitable for breeding ferruginous hawks in South Dakota, and they concluded that intensification of agriculture would probably further reduce the number of suitable areas. Harmata (1991) commented on the paucity of breeding raptors several km south of the Kevin Rim in an area with similar nesting substrates but where cultivation intensity was much higher.

Higher nest survival and productivity at the Kevin Rim in 1993 and 1994 among nests with higher densities of secondary roads within 1.6 km were probably also due to the greater abundance of ground squirrels found along roads than in grasslands. Ground squirrels were more abundant along roadsides, possibly because of a combination of increased vegetative density and disturbed soil, which may be more easily excavated by ground squirrels, found along roads. The level of disturbance associated with roads at the

Kevin area remained low (Van Horn 1993), and other vehicles were rarely observed during field research. Harmata (1991) reported no significant differences in productivity between ferruginous hawks that nested closer to and those that nested farther from paved roads, dirt roads, and vehicle trails at the Kevin Rim. Van Horn (1993) reported that ferruginous hawks at the Rim used secondary roads greater than in proportion to their availability but used primary roads less than expected. Bechard et al. (1990) found that ferruginous hawks in Washington nested farther from roads than Swainson's hawks. Gilmer and Stewart (1983) reported that pairs of ferruginous hawks that nested within 500 m of roads had similar nest success to pairs that nested farther from roads, and they believed the hawks acclimated to disturbances related to roads.

A possible explanation for the apparent positive impact of oil wells on ferruginous hawk nest survival may have more to do with the network of secondary roads associated with the oil fields. Although not quantified in this study, the density of secondary roads was obviously much greater among oil wells than in surrounding grassland areas. The increased abundance of ground squirrels, indicated by greater burrow density, associated with these roads may have benefited breeding ferruginous hawks that nested within 1.6 km of oil wells. Harmata (1991) reported that more productive pairs of ferruginous hawks at the Kevin Rim nested farther from active oil wells than less productive pairs. Van Horn (1993) reported that ferruginous hawks used oil fields for foraging greater than in proportion to their availability.

Larger clutch and brood sizes of ferruginous hawk nests further from nests of conspecifics and with fewer breeding pairs of raptors within 1.6 km indicates that productivity at the Kevin Rim may be influenced by intra- and interspecific competition. Schmutz (1977, 1989) reported that ferruginous hawk density and distribution was potentially affected by intra- and interspecific competition, and he noted that territorial competition for space by resident ferruginous hawks prevented a surplus of breeders from breeding. Schmutz et al. (1980) reported that ferruginous hawks that nested within 0.3 km of other *Buteos* were less successful in fledging ≥ 1 young than those that nested > 0.3 km from another pair of *Buteos*. Similarly, Johnsgard (1990:17) reported that in situations of close interspecific nesting among ferruginous, red-tailed, and Swainson's hawks, reductions in productivity were apparently the result of ecological overlap among the 3 species. Restani (1989, 1991) reported greater overlap in diet between ferruginous and red-tailed hawks than between Swainson's and ferruginous hawks.

The greater productivity of nests below 1200 m than those above 1200 m may have been an artifact of nest locations relative to cultivated fields. The highest nest elevations were associated with the southern portion of the main Rim; the area with the lowest cultivation intensity (Fig. 4).

Food Habits and Prey Density

Ground squirrels comprised the majority of prey items recorded in ferruginous hawk nests in 1993 and 1994, followed by lagomorphs and birds. Prey remains in nests in this study were similar to those reported by Harmata (1991), who found that ground squirrels accounted for 73% of ferruginous hawk prey based on pellet analysis. Olendorff (1993) summarized prey data from 20 studies and reported that mammals accounted for

83% by frequency and 95% by biomass of ferruginous hawk prey, whereas birds accounted for 13% by frequency and 4% by biomass. The remainder of prey items (3-4% by frequency and < 1% by biomass) consisted of amphibians, reptiles, and insects (Olendorff 1993).

Lagomorph density recorded during headlight surveys was higher on survey roads with > 25% cultivation than on those with no cultivation, however, the total number of lagomorphs recorded was so small that results should be regarded cautiously. Harmata (1991) reported that lagomorph numbers were significantly higher along survey routes that consisted of native grass/shrub habitats than along those in which cultivation intensity ranged from ≤ 17% to 100%. He also reported that lagomorph use of survey routes with a cultivation intensity of 25% was greater than in proportion to availability of this habitat type (Harmata 1991). The density of lagomorphs observed during headlight surveys declined steadily from 0.56/km in 1990 (Harmata 1991), to 0.19/km and 0.09/km in 1991 and 1992, respectively (Van Horn 1993), to 0.06/km in 1994. This decline in lagomorph numbers was concurrent with decreased ferruginous hawk breeding density and productivity (Zelenak and Rotella 1994) and may also influence nest survival.

The densities of active ground squirrel burrows on roadside and crop-edge transects were significantly greater than that on grassland transects. Ground squirrels were more abundant along roadsides, possibly because of a combination of increased vegetative density and disturbed soil, which may be more easily excavated by ground squirrels, found along roads. The greater density of burrows on the peripheries of cultivated fields is likely a response to the abundant food sources provided by such areas.

(Schmutz 1977, 1987b) also reported that ground squirrels occurred at unusually high densities near agricultural fields. Higher nest survival and productivity of ferruginous hawk nests closer to and with greater intensities of secondary roads and cultivated fields appears to be related to the greater abundance of ground squirrels found in these habitats.

Population Status

Between 1988 and 1994, the common study area at the Kevin Rim supported, on average, 18.5 occupied ferruginous hawk breeding territories. Using results from this study, which provide the most complete information on productivity, this number of nests would annually fledge 11 to 25 young hawks, 8 to 25 of which could be expected to survive to disperse from the area (numbers based on 95% confidence intervals for young fledged/occupied territory and juvenile post-fledging survival). Although these numbers probably vary annually depending on prey availability, predation, and weather, it is clear that the Kevin Rim is an important breeding area that annually produces young that survive to disperse. However, without sound knowledge of the annual survival rates of juveniles and adults from the area, it is impossible to determine if the local population of ferruginous hawks at the Kevin Rim is self-sustaining or if it plays an important role in the larger-scale metapopulation (source or sink) dynamics (Pulliam 1988) of the regional ferruginous hawk population.

Schmutz and Fyfe (1987) estimated a first year mortality rate of 66% for ferruginous hawks. Although this estimate was based on a limited number of band returns, it is the best available. Using this rate and an adult annual mortality rate of 25%

(based on data for other raptor species), Woffinden and Murphy (1989) estimated that breeding pairs must produce 1.5 young/year to maintain population stability. If these rates are appropriate for ferruginous hawks at the Kevin Rim, productivity at the Rim in 1993 and 1994 was inadequate to maintain the population. Van Horn (1993) reported that reproduction was also inadequate in 1990 and 1992. Thus, there is reason to believe that the Kevin Rim has been a population sink for ferruginous hawks during the past 5 years. Prey availability appears to be the factor that determines whether a breeding area serves as a source or a sink: DuBois' (1988) data indicated a minimum of 2.0 young fledged/ occupied territory at a time when white-tailed jackrabbits were apparently abundant on the study area. Further research is clearly needed at the Rim to determine how productivity and the population's growth rate respond over a variety of levels of prey availability. In particular, productivity data are needed for years with higher prey availability and for more years. These data, along with badly needed estimates of annual survival of adults and juveniles, could then be used to determine under what circumstances the Kevin Rim breeding population acts as a source or a sink and to better determine its role in the regional population dynamics of the species.

MANAGEMENT AND RESEARCH IMPLICATIONS

Breeding populations of raptors are most often limited by availability of suitable nest sites and food resources, both of which are indicators of breeding-habitat quality (Newton 1976, 1979). In the case of ferruginous hawks a third factor, human disturbance at nest sites, may also be important (Snow 1974; Call 1978, 1979; Olendorff et al. 1980; Jasikoff 1982; White and Thurow 1985). Vacant breeding territories at the Kevin Rim in 1993 and 1994 (and apparently in previous years) indicate that the breeding population is probably not limited by nest-site availability. Low levels of human activity in the area suggest that human-related disturbances probably directly affect only a small proportion of the breeding population annually (Van Horn 1993, this study). It appears, therefore, that breeding ferruginous hawks at the Kevin Rim are limited by prey abundance and availability.

Future research at the Rim should be aimed at developing an adaptive management plan to increase prey populations to benefit breeding raptors. Research is needed to determine which plant communities and habitat types provide optimal prey abundance, diversity, and availability. The influence of cattle-grazing, which occurs on nearly all uncultivated land at the Rim, has not been investigated but may impact breeding raptors (Call 1979, Olendorff 1993). Development of a rest-rotation grazing regime is a management option that could benefit breeding raptors by enhancing vegetative and prey diversity and prey abundance.

Levels of human disturbance related to oil development and agriculture do not currently appear to negatively impact breeding ferruginous hawks, however, increases in these activities pose a potential threat (Howard and Wolfe 1976; Blair and Schitoskey 1982; Schmutz 1987a, 1987b, 1989), and should be discouraged. Similarly, although low levels of cultivation may enhance prey numbers and ferruginous hawk reproductive success (Schmutz 1989, this study), increased cultivation could reduce the overall suitability of the area for breeding hawks. The Kevin Rim area currently provides 1 of only a few large tracts of relatively undisturbed grasslands surrounded by extensive areas of intensive cultivation (DuBois 1988, Harmata 1991).

Results of this study indicate that intra- and interspecific competition may be related to ferruginous hawk productivity at the Kevin Rim. Several areas of grasslands approximately 5 to 10 km east of the Rim appear to support large numbers of ground squirrels but lack suitable nesting substrates for ferruginous hawks. If they contain public lands, these areas may provide an opportunity for reducing competition among breeding pairs at the Rim through installation of artificial nesting platforms. Ferruginous hawks are versatile nesters and respond well to artificial nesting platforms, which may increase productivity by removing the threat from mammalian predators (Olendorff and Stoddart 1974, Olendorff et al. 1980, Houston and Bechard 1984, Schmutz et al. 1984, Olendorff 1993). In early spring 1995, 2 nesting platforms were built and installed by a landowner in the Kevin area who wished to encourage ferruginous hawks to nest near his wheat fields and thereby control ground squirrels and reduce crop losses. A pair occupied the area in 1995 and attempted to build a nest on 1 of the platforms but did not breed successfully.

Continued monitoring of raptor populations at the Kevin Rim should also be a priority. Long-term databases on raptor reproductive success are rare, but they are critical for detecting trends in breeding populations (Olendorff 1993). Research at the Rim has provided information on raptor breeding from 1988 to 1994, excluding 1989. Minimal data on ferruginous hawk density and productivity were also gathered in 1995 (Zelenak, unpubl. data). Because of its high density of breeding raptors and its relatively small size, the Kevin Rim offers excellent potential for a long-term monitoring site for breeding raptors in Montana. In fact, the Rim is the only study area in the state at which research has been conducted for > 2 consecutive years.

Gilmer and Stewart (1983) believed that small areas of high nesting density serve as focal points of production of ferruginous hawks for large regions. Further, Schmutz (1987b) concluded that core populations of ferruginous hawks must remain sufficiently large so that the species is not threatened by perturbations that cause periodic population fluctuations. Continued annual research of the Rim's high-density breeding population of ferruginous hawks is recommended to determine causes of fluctuations in breeding numbers and productivity. Maintenance or improvement of ferruginous hawk breeding success at the Kevin Rim may be important to the health of the larger regional population.

LITERATURE CITED

Andersen, D. E., O. J. Rongstad, and W. R. Mytton. 1990. Homerange changes in raptors exposed to increased human activity levels in southeastern Colorado. Wildl. Soc. Bull. 18:134-142.

Atkinson, E. C. 1993. Ferruginous hawk (Buteo regalis) monitoring on the Dillon Resource Area of southwest Montana; 1993. Bureau of Land Manage., Dillon, Mont. 21pp.

_____. 1995. Survey and monitoring guidelines for ferruginous hawks in Montana. Raptor Research Center, Boise State Univ., Boise, Id. 42pp.

Bechard, M. J. 1981. Historical nest records for the ferruginous hawk in Manitoba. Can. Field-Nat. 95:467-469.

_____, R. L. Knight, D. G. Smith, and R. E. Fitzner. 1990. Nest site and habitats of sympatric hawks (*Buteo* spp.) in Washington. J. Field Ornithol. 61:159-170.

Bendire, C. 1892. The American rough-legged hawk. Life histories of North American birds. U.S. Nat. Mus. Spec. Bull. 1:259-262.

Bent, A. C. 1937. Life histories of North American birds of prey. Order Falconiformes. (Part 1). Smithsonian Institution, Washington, D.C. 409pp.

Black, A. 1992. Ferruginous hawk reproduction and habitat survey. Challenge cost share report. Northern Rockies Conservation Cooperative, Jackson, Wyo. 30pp.

Blair, C. L. 1978. Breeding history and prey selection of ferruginous hawks in northwestern South Dakota. MS. Thesis. South Dakota State Univ., Brookings. 60pp.

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

Borenstein, M., and J. Cohen. 1988. Statistical power analysis: A computer program. Lawrence Erlbaum Assoc., Inc. Hillsdale N. J.

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

Call, M. W. 1978. Nesting habitats and surveying techniques for common western raptors. U.S. Bur. Land Manage. Tech Note T/N-316. 115pp.

_____. 1979. Habitat management guides for birds of prey. U.S. Bur. Land Manage. Tech Note T/N-338. 70pp.

Cameron, E. S. 1914. The ferruginous rough-leg, Archibuteo ferrugineus in Montana. Auk 31:159-167.

Climatedata. 1995. CD-ROM advanced with flags, version 6.00. Hydrosphere Data Products, Inc. 1002 Walnut, Suite 200, Boulder, Colo. 80302.

Cottrell, M. J. 1981. Resource partitioning and reproductive success of three species of hawks (Buteo spp.) in an Oregon prairie. MS. Thesis. Oregon State Univ., Corvallis. 71pp.

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

DuBois, K. L. 1988. High nesting density of birds of prey near Kevin, Montana. Final Report. U.S.D.I., Bureau of Land Management, Great Falls, Mont. 8pp.

Ensign, J. T. 1983. Nest site selection, productivity, and food habits of ferruginous hawks in southeastern Montana. MS. Thesis. Montana State Univ., Bozeman. 83pp.

Fitzner, R. E., D. Berry, L. L. Boyd, and C. A. Rieck. 1977. Nesting of ferruginous hawks (Buteo regalis) in Washington, 1974-75. Condor 79:245-249.

Flath, D. L. 1991. Species of special interest or concern. Montana Dept. of Fish, Wildlife, and Parks. Wildlife Division, Helena, Mont. 7pp.

Fyfe, R. W. 1976. Status of Canadian raptor populations. Can. Field Nat. 90:370-375.

_____, and R. R. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Can. Wildl. Serv. Occas. Pap. 23:1-17.

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

Gates, J. M. 1972. Red-tailed hawk populations and ecology in east-central Wisconsin. Wils. Bull. 84:421-433.

Gilmer, D. S., D. L. Evans, P. M. Konrad, and R. E. Stewart. 1985. Recoveries of ferruginous hawks banded in south-central North Dakota. J. Field Ornithol. 56:184-187.

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

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

_____. 1991. Impacts of oil and gas development on raptors associated with the Kevin Rim, Montana. Report to Bureau of Land Management, Great Falls, Mont. 98pp.

Hosmer, D. W. , Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York, NY. 107pp.

Houston, C. S., and M. Bechard. 1984. Decline of the ferruginous hawk in Saskatchewan. Amer. Birds 38:166-170.

Howard, R. P. 1975. Breeding ecology of the ferruginous hawk in northern Utah and southern Idaho. MS. Thesis. Utah State Univ., Logan. 59pp.

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

Jasikoff, T.M. 1982. Habitat suitability index models: Ferruginous hawk. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.10. 18pp.

Johnsgard, P. A. 1990. Hawks, eagles, and falcons of North America. Smithsonian Institution Press, Washington, D.C. 403pp.

Johnson, S. J. 1975. Productivity of the red-tailed hawk in southwestern Montana. Auk 92:732-736.

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 biology in southeastern Oregon. MS. 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.

Luttich, S.M., L. B. Keith, and J. D. Stephenson. 1971. Population dynamics of the red-tailed hawk (Buteo jamaicensis) at Rochester, Alberta. Auk 88:75-87.

Mader, W. J. 1978. A comparative nesting study of red-tailed hawks and Harris' hawks in southern Arizona. Auk 95:327-337.

Meyers, L. H. 1987. Nesting ecology of ferruginous hawks in southwest Montana. Paper presented at the Montana Nongame Symposium. Feb. 11, 1987. Kalispell, Mont. 14pp.

Moritsch, M. Q. 1985. Photographic guide for aging nestling ferruginous hawks. U. S. Bur. Land Manage. Boise, Id. 19pp.

Newton, I. 1976. Population limitation in diurnal raptors. Can. Field-Natur. 90:274-300.

_____. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD. 399pp.

Olendorff, R. R. 1993. Status, biology, and management of ferruginous hawks: a review. Raptor Res. and Tech. Asst. Cen., Spec. Rep. U.S. Dep. Interior, Bur. Land Manage. Boise, Id. 84pp.

_____, 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. Raptor Res. Found., Inc., Vermillion, S.D.

_____, R. S. Motroni, and M. W. Call. 1980. Raptor management-the state of the art in 1980. U.S.D.I. Bur. Land Manage. Tech. Note 345. 56pp.

_____, D. D. Bibles, M. T. Dean, J. R. Haugh, and M. N. Kochert. 1989. Raptor habitat and management under the U.S. Bureau of Land Management multiple-use mandate. Raptor Res. Rep. 8:1-80.

Postupalsky, S. 1974. Raptor reproductive success: Some problems with methods, criteria, and terminology. Raptor Res. Rep. 2:21-31.

Powers, L. R., and T. H. Craig. 1976. Status of nesting ferruginous hawks in the Little Lost River Valley and vicinity, southeastern Idaho. Murrelet 57:46-47.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652-661.

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

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

Salt, W. P. 1939. Notes on recoveries of banded ferruginous rough-legged hawks. Bird Banding 10:80-84.

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

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

_____. 1987a. Effect of agriculture on ferruginous and Swainson's hawks. J. Range Manage. 40:438-440.

_____. 1987b. Estimate of population size and probable causes of population stability in ferruginous hawks in southeastern Alberta. Univ. of Saskatchewan, Saskatoon. 45pp.

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

_____, S. M. Schmutz, and D. A. Boag. 1980. Coexistence of three species of hawks (*Buteo* spp.) in the prairie parkland ecotone. Can. J. Zool. 58:1075-1089.

_____, R. W. Fyfe, D. A. Moore, and R. A. Smith. 1984. Artificial nests for ferruginous and Swainson's hawks. J. Wildl. Manage. 48:1009-1013.

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

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

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

Smith, D. G., and J. R. Murphy. 1978. Biology of the ferruginous hawk in central Utah. Sociobiology 3:79-98.

_____. 1979. Breeding responses of raptors to jackrabbit density in the eastern Great Basin desert of Utah. Raptor Res. 13:1-14.

_____, J. R. Murphy, and N. D. Woffinden. 1981. Relationships between jackrabbit abundance and ferruginous hawk reproduction. Condor 83:52-56.

Snow, C. 1974. Habitat management series for unique and endangered species: Ferruginous hawk (Buteo regalis). U.S. Bur. Land Manage. Tech Rep. No. T/N-255. Denver, Colo. 23pp.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. Second ed. McGraw-Hill Book Co., New York, NY. 633pp.

Ure, J., P. Briggs, and S. W. Hoffman. 1991. Petition to list as endangered the ferruginous hawk (Buteo regalis), as provided by the Endangered Species Act of 1973, as amended in 1982. Ferruginous Hawk Project, Salt Lake City, Utah. 9pp.

U.S. Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants; notice of finding on petition to list the ferruginous hawk. Federal Register 57 (161):37507-37513. August 19, 1992.

Van Horn, R. C. 1993. Ferruginous hawk and prairie falcon reproductive and behavioral responses to human activity near the Kevin Rim, Montana. MS. Thesis. Montana State Univ., Bozeman. 86pp.

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

Weston, J. B. 1969. Nesting ecology of the ferruginous hawk Buteo regalis. Brigham Young Univ. Sci. Bull., Biol. Ser. 10:25-36.

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

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, Calif. 383pp.

Williams, D. C., and F. Campbell. 1988. How the Bureau of Land Management designates and protects areas of critical environmental concern: A status report with a critical review by the Natural Resources Defense Council. Natural Areas Journal 8:231-237.

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

Woffinden, N. D., and J. R. Murphy. 1977. Population dynamics of the ferruginous hawk during a prey decline. Great Basin Natur. 37:411-425.

_____, and _____. 1983. Ferruginous hawk nest site selection. J. Wildl. Manage. 47:216-219.

_____, and _____. 1989. Decline of a ferruginous hawk population: A 20-year summary. J. Wildl. Manage. 53:1127-1132.

Zelenak, J. R., and J. J. Rotella. 1994. Impact of human activities on breeding ferruginous hawks at the Kevin Rim in northern Montana. Pages 47-53 in S. Q. Foster, S. Pas, S. Rush, and O. Thorne, II, eds. Proc. 6th annual Symposium on Impacted Wildlife, Thorne Ecological Institute, Boulder, Colo.

APPENDIX

Table 9. Locations, status, and productivity of occupied ferruginous hawk nests at the Kevin Rim, 1993-1994.

Nest Location		Year	Adult color			Productivity		Fledgling
UTMN	UTME	Occupied	F	M	Eggs	Nestlings	Fledged	color
5403530	421420	1993	D	L	2	1	1	1D
		1994	D	L	3	3	3	3D
5403560	421840	1993	L	L	3	3	2	2L
5403660	421630	1994	L	L	3	3	1	1L
5403720	423640	1994	L	D	2	2	2	1L,1D
5404980	423190	1993	L	L	3	3	2	2L
		1994	L	L	3	2	1	1L
5405100	424610	1993	L	D	0	0	0	
5405370	425290	1993	L	L	0	0	0	
5405380	422310	1993	L	L	3	3	3	3L
		1994	L	L	0	0	0	
5405920	426920	1993	L	L	0	0	0	
5407050	424730	1994	L	L	0	0	0	
5407910	426290	1993	L	L	2	2	2	2L
		1994	L	L	0	0	0	
5407920	426430	1994	L	L	2	2	0	
5408330	426640	1993	D	L	0	0	0	
		1994	D	L	2	2	0	
5409510	426730	1993	D	L	3	3	0	
		1994	D	L	4	4	0	
5409750	426880	1994	L	L	2	0	0	
5409950	427160	1993	L	L	3	3	0	
5410060	431640	1994	L	D	4	4	3	2D,1L
5410710	425470	1994	L	L	4	4	0	
5410870	425660	1993	L	L	3	3	3	3L
5411970	425120	1993	L	L	3	3	3	3L
		1994	L	L	3	3	2	2L
5412290	428720	1994	L	L	3	3	2	2L
5412650	429620	1993	L	L	3	2	0	

Table 9. (Continued).

Nest Location		Year	Adult color			Productivity		Fledgling
UTMN	UTME	Occupied	F	M	Eggs	Nestlings	Fledged	color
5412650	429620	1994	L	L	0	0	0	
5412690	424560	1994	L	L	5	0	0	
5412930	429960	1993	L	L	4	4	4	4L
5413460	424770	1993	L	L	2	2	2	2L
5413910	425470	1993	L	D	2	2	0	
5414090	424740	1993	L	L	3	3	0	
		1994	L	L	0	0	0	
5415530	423490	1993	L	L	0	0	0	
		1994	L	L	1	0	0	
5416190	424940	1993	D	L	0	0	0	
		1994	L	L	0	0	0	
5416880	425010	1993	L	L	2	2	2	2L
5416900	425110	1994	D	L	1	1	1	1D
5417590	425460	1993	L	L	2	0	0	
		1994	L	L	1	0	0	
5417790	423180	1993	L	L	3	2	0	
		1994	L	L	4	4	4	4L
5418290	424120	1993	D	L	4	2	0	
		1994	D	L	4	4	3	3D

Table 10. Locations and productivity of occupied nests/eyries of other raptors at the Kevin Rim, 1993-1994.

Species[a]	Location UTMN	UTME	Year Occupied	Productivity
PF	5403160	422280	1993	Unknown
PF			1994	Fledged ≥ 2
PF	5403410	422840	1993	Unknown
PF			1994	Unknown
PF	5403530	421980	1993	Fledged ≥ 3
PF	5403600	423550	1993	Unknown
PF			1994	Fledged 5
PF	5403610	421790	1994	Fledged ≥ 3
PF	5403980	423690	1993	Unknown
PF			1994	Unknown
PF	5404410	423970	1993	Unknown
PF			1994	Unknown
PF	5405710	424400	1994	Unknown
PF	5406040	424610	1993	Unknown
PF	5406420	424720	1993	Unknown
PF	5407450	424980	1994	Unknown
PF	5407740	425780	1993	Unknown
PF	5408210	426690	1993	Unknown
PF			1994	Fledged ≥ 2
PF	5409800	427050	1993	Unknown
PF			1994	Fledged ≥ 1
PF	5412800	424710	1993	Unknown
PF			1994	Fledged ≥ 2
PF	5414180	424760	1993	Unknown
PF	5414360	425190	1993	Unknown
PF	5415680	424350	1993	Unknown
PF			1994	Unknown
PF	5416440	425290	1993	Unknown
PF			1994	Unknown

Table 10. Continued.

Species[a]	Location UTMN	UTME	Year Occupied	Productivity
PF	5417310	423030	1993	Unknown
PF			1994	Fledged 5
PF	5417500	425040	1993	Unknown
PF			1994	Unknown
PF	5417950	424060	1994	Fledged ≥ 3
PF	5418050	423690	1993	Unknown
AK	5404060	423720	1993	Unknown
AK	5404470	424020	1994	Unknown
AK	5404780	428430	1993	Fledged 5
AK			1994	Fledged ≥ 2
AK	5404950	424310	1993	Unknown
AK	5405100	424610	1994	Unknown
AK	5406490	424740	1994	Unknown
AK	5409310	427090	1994	Unknown
AK	5409660	425930	1993	Unknown
AK	5415750	424520	1994	Unknown
AK	5417720	423320	1993	Unknown
AK	5417790	424070	1993	Unknown
AK	5418230	425570	1994	Unknown
GE	5403430	422680	1993	Fledged 2
GE			1994	Fledged 2
GE	5404970	424400	1993	Fledged 1
GE	5405100	424610	1994	Failed
GE	5412290	428720	1993	2 nestlings, failed
GE	5413910	425470	1994	Failed
GE	5417480	424500	1993	Fledged 2
GE			1994	Failed
RT	5406940	424650	1993	Failed

Table 10. Continued.

Species[a]	Location UTMN	UTME	Year Occupied	Productivity
RT	5411470	425210	1993	Fledged 3
RT			1994	Failed
RT	5412690	424560	1993	Failed
RT	5415340	424660	1993	Failed
RT			1994	Failed
RT	5417330	422680	1994	Fledged 1
RT	5417480	423660	1994	Fledged 2
RT	5417700	424740	1993	Fledged 3
SW	5412170	424940	1994	Unknown
SW	5413340	428980	1993	Unknown
SW			1994	Unknown
SW	5417200	425920	1994	2 nestlings
GHO	5407910	426290	1994	Fledged 2
GHO	5407960	425940	1993	Fledged ≥ 2
GHO	5408720	426130	1993	Fledged 3
GHO			1994	Fledged 2
GHO	5415370	423480	1993	Unknown
BO	5409930	429510	1994	Fledged ≥ 6

[a] PF = Prairie Falcon
AK = American kestrel
GE = Golden eagle
RT = Red-tailed hawk
SW = Swainson's hawk
GHO = Great-horned owl
BO = Burrowing owl

Table 11. Juvenile ferruginous hawks banded and radio-marked at the Kevin Rim, 1993-1994.

Year	USFWS Band No.	Nest Location UTMN	UTME	Weight (g)[a]	Hallux (mm)[b]	Tarsus (mm)[c]	Sex[d]	Color
1993	1207-27416	5413460	424770					L
1993	1207-27471	5403530	423420	1490	17.8	12.7	F	D
1993	1207-27418	5405380	422310	1150	16.0	11.4	M	L
1993	1207-27419	5405380	422310					L
1993	1207-27420	5405380	422310					L
1993	1207-44509	5404980	423190	860	13.6	9.8	M	L
1993	1207-44510	5404980	423190	1620	15.0	12.9	F	L
1993	1207-44511	5412930	429960	1200	12.5	10.0	M	L
1993	1207-44512	5407910	426290	1600	18.1	14.3	F	L
1993	1207-44513	5407910	426290					L
1993	1207-44514	5410870	425660	1220	14.5	11.7	M	L
1993	1207-44515	5410870	425660					L
1993	1207-44516	5410870	425660					L
1993	1207-44517	5411970	425120	1760	17.8	13.2	F	L
1993	1207-44518	5411970	425120					L
1993	1207-58758	5412930	429960	1525	17.2	12.1	F	L
1993	1207-58759	5412930	429960					L
1993	1207-58760	5413460	424770	1125	13.3	11.2	M	L
1993	1207-62866	5411970	425120					L
1993	1207-62867	5403560	421840	1180	14.5	10.6	M	L
1994	1207-62868	5417790	423180	1620	17.4	14.9	F	L
1994	1207-62869	5417790	423180	1030	14.3	10.8	M	L
1994	1207-62870	5417790	423180					L
1994	1207-62871	5417790	423180					L
1994	1207-62872	5403530	423430	1710	16.0		F	D
1994	1207-62873	5403530	423420	1160	12.8		M	D
1994	1207-62874	5410060	431640	1680	18.4	15.2	F	D
1994	1207-62875	5410060	431640	1730	16.4	14.8	F	D

Table 11. (Continued)

Year	USFWS Band No.	Nest Location UTMN	UTME	Weight (g)[a]	Hallux (mm)[b]	Tarsus (mm)[c]	Sex[d]	Color
1994	1207-62876	5410060	431640	1630	18.4	13.9	F	L
1994	1207-62877	5403720	423640	1620	16.5	16.5 (?)	F	D
1994	1207-62878	5403720	423640					L
1994	1207-62879	5411970	425120	1580	19.0	14.7	F	L
1994	1207-62880	5411970	425120	1120	14.9	11.2	M	L
1994	1207-61881	5418290	424120					D
1994	1207-62882	5418290	424120					D
1994	1207-62883	5418290	424120	1370	17.0	13.4	F	D
1994	1207-62884	5418290	424120	1040	13.4	10.9	M	D
1994	1207-62885	5403660	421630	1340	16.5	14.0	F	L
1994	1207-62886	5403660	421630	1560	18.1	14.2	F	L
1994	1207-62887	5404980	423190	1090	15.4	12.6	M	L
1994	1207-62888	5402190	433380	1560	18.0	15.1	F	L
1994	1207-62889	5402190	433380	1230	16.8	11.9	M	L
1994	1207-62890	5402190	433380	1730	19.0	14.6	F	L
1994	1207-62891	5412290	428720	1240	16.0	12.3	M	L
1994	1207-62892	5412290	428720	1150	15.0	12.5	M	L
1994	1207-62893	5416900	425110	1040	14.5	12.0	M	D

[a]Weights are reported only for radio-marked juveniles.
[b]Flexed hallux diameter measured at widest point.
[c]Anterior-posterior diameter measured at narrowest part of tarsus.
[d]Sex determined based on weight (Female > 1300 g, Male < 1300 g).

Table 12. Numbers of breeding pairs and breeding densities of raptors at the Kevin Rim, 1993-1994.

Species	1993		1994	
	Breeding pairs	Breeding density (km^2/pair)	Breeding pairs	Breeding density (km^2/pair)
Ferruginous hawk	24	7.12	24	7.12
Prairie falcon	19	9.00	17	10.06
American kestrel	6	28.49	7	24.42
Red-tailed hawk	5	34.19	4	42.74
Golden eagle	4	42.74	4	42.74
Swainson's hawk	1	170.94	3	56.98
Great-horned owl[a]	3	56.98	2	85.47
Burrowing owl[a]	0		1	170.94
All Raptors[b]	62	2.76	62	2.76

[a]Additional breeding pairs may have been undetected.
[b]Northern harriers were common on the study area, and short-eared owls were occasionally observed, however no nests of these species were located.