Ferruginous Hawk (*Buteo regalis*)
A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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Cameron P. Collins and Timothy D. Reynolds, Ph.D.
TREC, Inc.
4276 E 300 N
Rigby, Idaho 83442

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AUTHORS' BIOGRAPHIES

Cameron P. (Cam) Collins received his M.S. (Wildlife Resources) in 2004 from the University of Idaho and a B.S. (Terrestrial Ecology) in 1995 from Western Washington University. His master's research investigated the ecology of Columbian sharp-tailed grouse associated with reclaimed mined lands and native shrub-steppe in Colorado. He has participated in a reintroduction program for the Hawaiian crow, and an investigation of the status of the Hawaiian hawk for the U.S. Fish and Wildlife Service. He has also spent time on research projects with northern goshawks and northern spotted owls, and he was part of an effort to eradicate feral ungulates from Santa Catalina Island. He is currently conducting a radio-telemetry study to investigate the effects of wind power development on the ecology of greater sage-grouse in southeastern Idaho for TREC, Inc.

Timothy D. (Tim) Reynolds is President and owner of TREC, Inc., a consulting firm specializing in environmental services and ecological research in Rigby, Idaho. He received a Ph.D. in Zoology (Ecology emphasis) from Idaho State University in 1978 and a M.S. (Biology) and B.S. (Biology, Comprehensive) from Illinois State University in 1974 and 1972, respectively. During his career he has been a Visiting Professor of Biology at Boise State University, Radioecologist for the U.S. Department of Energy, and a Research Ecologist and Director of Operations for the Environmental Science and Research Foundation. He has conducted and coordinated ecological research on birds, mammals, reptiles, and aspects of hazardous waste management; he has nearly 50 publications in the technical literature.

COVER PHOTO CREDIT

Light phase ferruginous hawk (*Buteo regalis*) in South Dakota. © Terry L. Stohl (http://sdakotabirds.com). Used with permission.

LIST OF ERRATA

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE FERRUGINOUS HAWK

Status

The current global heritage status rank of the ferruginous hawk (*Buteo regalis*) is G4, apparently secure. Although the ferruginous hawk was rejected for listing under the Endangered Species Act, it is generally agreed that moderate declines in its distribution have occurred over the past century, especially at the northern periphery of its breeding range. Within USDA Forest Service (USFS) Region 2, the ferruginous hawk has probably also undergone some level of range retraction, but the lack of a comprehensive, consistent, and long-term monitoring program has made determination of its status difficult. A tendency toward nomadic behavior further complicates the accurate determination of ferruginous hawk population trends. Therefore, apparent regional and local population trends may not accurately reflect range-wide population trends. As much as 20 percent of the winter range of the ferruginous hawk may be in the Mexican portion of the Great Plains, where little is known regarding its distribution, abundance, or over-winter survival. Currently, all states within Region 2 recognize the ferruginous hawk as a species in need of special conservation action. It is listed as a sensitive species on lands administered by the USFS and U.S. Bureau of Land Management, and it is a Management Indicator Species on two national forests within Region 2, reflecting its importance as an indicator of the overall health of the grassland and shrub-steppe ecosystems that it occupies.

Primary Threats

The primary threats to the ferruginous hawk include lack of secure nest substrates, lack of suitable prey species, human disturbance during the reproductive period, lack of suitable habitat surrounding nest sites, and threats to survival of adult hawks. Most of these primary threats, as well as lesser threats, originate from the loss (to cultivation and urbanization) of historically occupied habitat, or alteration (through overgrazing by domestic livestock, altered fire regimes, and conversion to less diverse landscapes) that leads to a significant reduction in small mammal populations, the primary food source of ferruginous hawks. While all threats operate on a local scale, it should be understood that habitat loss and degradation occur on a broad-scale, and that curbing urban sprawl and retaining large, intact tracts of grassland and shrub-steppe present the major challenge to preserving viable populations of ferruginous hawks.

Primary Conservation Elements, Management Implications and Considerations

Ferruginous hawks in Region 2 could benefit from the development and implementation of a comprehensive population monitoring program, including an effort to track breeding abundance through sightability modeling, demographic monitoring to help explain any observed trends in the population, and satellite telemetry monitoring to investigate factors affecting survival of adults. Ferruginous hawk habitat would best be conserved through an ecosystem management approach that emphasizes diversity of native flora and small mammal populations, and protection and enhancement of currently occupied habitat. Although important, management activities that focus solely on a local scale to protect individual nest sites or small, isolated populations are not likely to conserve ferruginous hawk populations within Region 2 over the long-term.

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INTRODUCTION

This conservation assessment is one of many intended to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS; **Figure 1**). The ferruginous hawk (*Buteo regalis*) is the focus of this assessment because of its designation as a sensitive species. A sensitive species is a plant or animal species whose population viability has been identified as a concern by a Regional Forester because of its significant current or predicted downward trend in abundance and/or distribution. The ferruginous hawk is also classified as a Management Indicator Species (MIS) on two national forests in Region 2. Management of a sensitive species and MIS, such as the ferruginous hawk, requires a thorough knowledge of its biology and ecology to adequately address threats to its conservation and successful management. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments are a critical component of the Rocky Mountain Region Species Conservation Project. This conservation assessment was crafted to provide biologists, land managers, and the public with a concise, yet comprehensive document encompassing the biology, ecology, conservation, and management of the ferruginous hawk in Region 2, using the most current scientific knowledge. The broad range of the assessment limits the scope of the work to critical summaries of scientific knowledge and discussions of broad implications of that knowledge and areas where additional information is needed. This assessment does not focus on developing prescriptive management recommendations. Rather, it provides a foundation

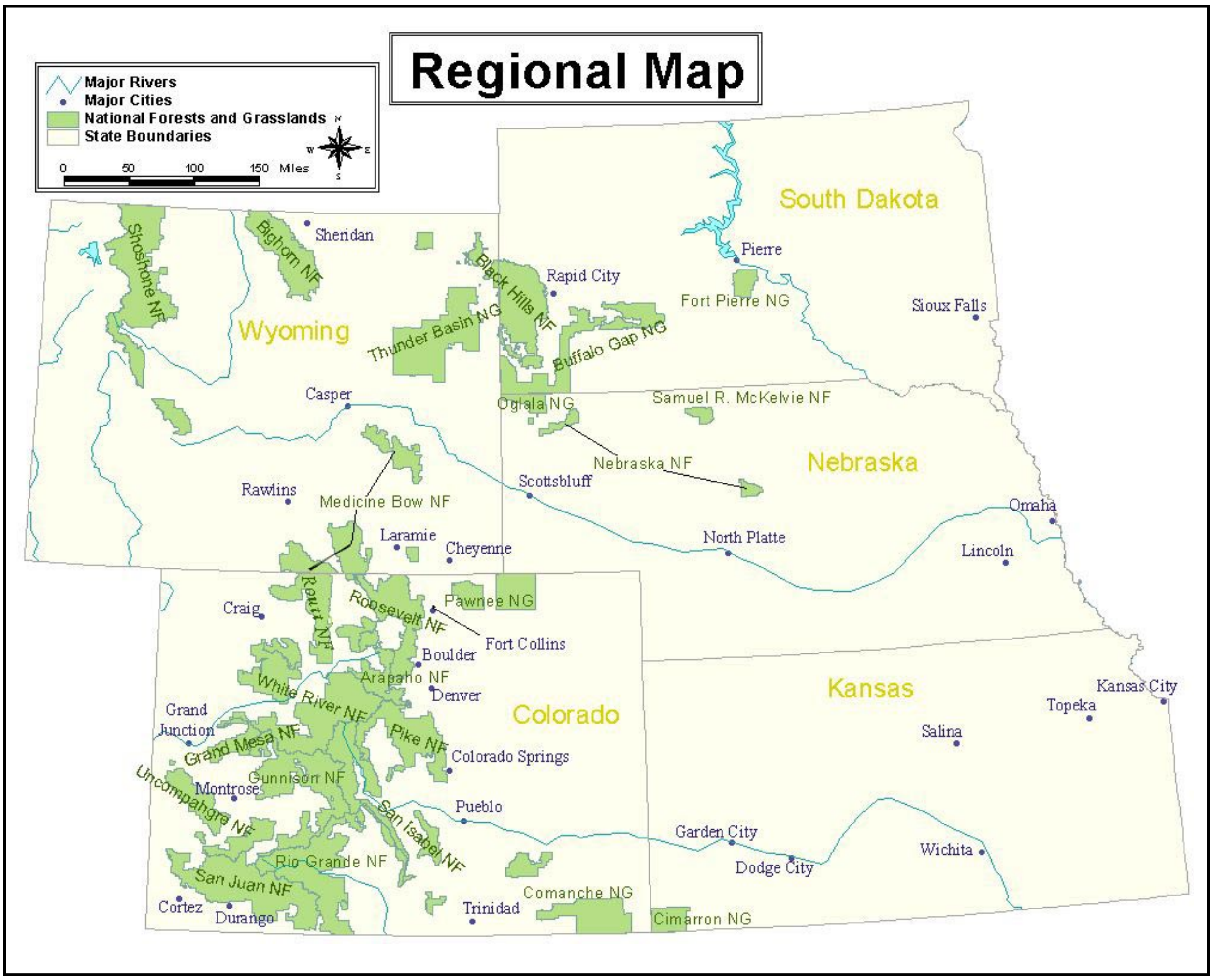


Figure 1. Boundaries of the lands administered by USDA Forest Service, Rocky Mountain (Region 2).

upon which conservation, restoration, and/or proactive management of the ferruginous hawk may be based. This foundation includes a framework of the parameters needed to ensure species persistence, what is currently missing from that framework, and provides guidance regarding strategic actions within that framework designed to maintain the viability of ferruginous hawk populations throughout Region 2.

Scope

The scope of this assessment includes the biology, ecology, conservation, and management of the ferruginous hawk with specific reference to the geologic and ecologic characteristics of the USFS Rocky Mountain Region. Although much of the referenced literature originates from studies outside the region, this assessment attempts to place that literature in the ecological context of the central and southern Rocky Mountains. The ecological status of the ferruginous hawk is addressed in the context of its current environment; however, historic elements are considered in the synthesis.

In producing this conservation assessment, we reviewed refereed literature, non-refereed literature, research reports, and data accumulated by resource management agencies. Not all materials regarding the ferruginous hawk are referenced, but an effort was made to review as much material as possible. The assessment emphasizes refereed literature because this is the accepted standard in science and is considered the most reliable and accurate. However, non-refereed material was used in this assessment when refereed information was unavailable, with special attention paid to the fact that it may not have been as reliable as refereed publications. As in all studies limited to a portion of a species' range, the application of information contained in this assessment may not be fully relevant to regions other than Region 2.

Treatment of Uncertainty

Romesburg (1981) defined knowledge as "the set of ideas that agree or are consistent with the facts of nature….discovered through the application of scientific methods." Unreliable knowledge is the set of false ideas mistaken for knowledge. Because the wildlife sciences are not ideally suited to the application of strict experimental rigor (Ratti and Garton 1994), we realize that much of what we take for knowledge in this assessment may be based on "laws of association" acquired through natural history observations, logical deduction, or inference rather than on experimental tests of specific hypotheses. Therefore, in this assessment, data obtained through sound experimental approaches were treated as the most reliable. Data gleaned using other approaches were considered to have merit if they withstood critical evaluation, and were integrated into the overall assessment strategy. Sometimes, data were conflicting or contradictory, leading to conclusions with a large degree of uncertainty. In this assessment, we either present the author's evaluation of uncertainty, or we provide a qualitative discussion when it is relevant to alternate interpretations of data.

Publication of Assessment on the World Wide Web

To facilitate the use of species conservation assessments, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the Web makes them accessible to agency biologists and the public more rapidly than publication as hard copy. In addition, publication on the Web facilitates updating or revising assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, which chose two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality of scientific communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Currently, the ferruginous hawk has a global heritage status rank of G4 (apparently secure), and national heritage status rank of N4B, N4N (B = apparently secure breeding population; the latter N = apparently secure non-breeding population) in the United States, and N3B (vulnerable breeding population) in Canada (NatureServe 2004). The ferruginous hawk was petitioned for listing under the federal Endangered Species Act in 1991 (Ure et al. 1991), but the petition was rejected because it "presented information insufficient to conclude that the required action may be warranted" (U.S. Fish and Wildlife Service 1992).

Throughout Canada, the ferruginous hawk was designated as Threatened in 1980, and as Vulnerable in 1995 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2005). In Alberta, the ferruginous hawk is considered an endangered species under the Alberta Wildlife Act (Schmutz 1999). In Mexico, the ferruginous hawk is protected only under the Migratory Bird Treaty Act, which is rarely enforced (Bechard and Schmutz 1995).

The ferruginous hawk is currently listed as a sensitive species by the USFS and the U.S. Bureau of Land Management (BLM) wherever the species occurs on lands administered by said agencies within Region 2. A sensitive species is a species recognized to be in need of special management to avoid being placed on a Federal or State list. In addition, the Arapahoe-Roosevelt and Pike-San Isabel national forests currently designate the ferruginous hawk as a Management Indicator Species (MIS), which is a "species selected because its welfare is presumed to be an indicator of the welfare of other species sharing similar habitat requirements", and "a species which reflects ecological changes caused by land management activities". As a MIS, the ferruginous hawk is intended to serve as a barometer for the effects of management activities on the plant and animal species associated with grassland (Comanche and Pawnee National Grasslands) and grassland/shrub-steppe communities on the Arapahoe-Roosevelt and Pike-San Isabel national forests.

The National Forest Management Act of 1976 (NFMA, 16 U.S.C. 1600 (note)) requires the USFS to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area" on National Forest System lands. The USFS recently adopted a final planning rule (U.S. Department of Agriculture 2004) that focuses on ecological sustainability rather than individual species viability, as in previous planning and implementation regulations. As an element of the grassland and shrub-steppe ecosystems of Region 2, the ferruginous hawk will be managed by the USFS under a "complementary ecosystem and species diversity approach for ecological sustainability" (U.S. Department of Agriculture Forest Service 2004). In addition, as a sensitive species and a MIS on two Region 2 forests, the USFS has recognized that the ferruginous hawk may need special management consideration to meet the requirements of the NFMA and the new planning rule.

The Colorado Division of Wildlife lists the ferruginous hawk as a Species of Special Concern (Colorado Division of Wildlife 2002). The Wyoming Game and Fish Department designates the ferruginous hawk as a Species of Special Concern with a Native Species Status 3, meaning, in this case, that the species is widely distributed but there is on-going significant loss of habitat and the species is sensitive to human disturbance (http://gf.state.wy.us/downloads/pdf/nongame/WYBirdMammHerpAtlas04.pdf). The Kansas Department of Wildlife and Parks classifies the ferruginous hawk as a Species in Need of Conservation (Kansas Biological Survey 2000) while the Nebraska Game and Parks Commission classifies it as a Species of Concern (Nebraska Natural Heritage Program 1996). The South Dakota Department of Game Fish and Parks does not accord the ferruginous hawk any special conservation status. State heritage program ranks for the ferruginous hawk in each state in Region 2 are presented in **Table 1**. Multiple non-governmental organizations (NGOs) have recognized that the ferruginous hawk may require special management attention to ensure its persistence. The ferruginous hawk is included on Audubon's Watchlist 2002, and Partners in Flight recognizes the species as a high priority species for conservation efforts.

Existing Legal Mechanisms, Management Plans, and Conservation Strategies

The ferruginous hawk is protected from "take" by the federal Migratory Bird Treaty Act (MBTA) and is managed as a non-game species by states. Provisions do, however, provide for the capture of raptors in accordance with 'license to take falcons' regulations issued by each state. As a federally designated sensitive species (USFS, BLM), the ferruginous hawk is included in the resource management plans of the USFS and the BLM. To our knowledge, only the USFS has prepared a regional (Great Plains) species-specific conservation assessment (Gillihan et al 2004a) and conservation strategy (Gillihan et al 2004b) for the ferruginous hawk. Washington State has prepared a recovery plan for the ferruginous hawk (Richardson 1996). These documents address threats, research and monitoring needs, population status and trends, and management priorities. The U.S. Fish and Wildlife Service (USFWS) prepared a Habitat Suitability Index model for the ferruginous hawk (Jasikoff 1982), but its complexity and lack of field verification tests decrease its management utility (Olendorff 1993).

Most states within Region 2 have some sort of management that specifically addresses ferruginous hawk conservation, or that is potentially beneficial to them. The Colorado Division of Wildlife initiated a

Table 1. Breeding and non-breeding state heritage ranks for the ferruginous hawk in Region 2.

	South Dakota	Nebraska	Kansas	Wyoming	Colorado
Breeding					
Critically imperiled					
Imperiled		X	X		
Rare/local					X
Apparently secure	X			X	
Secure					
Irregular*					
Non-breeding					
Critically imperiled					
Imperiled		X			
Rare/local					
Apparently secure			X		X
Secure				X	
Irregular*	X				

*Too irregular, transitory, or dispersed to be reliably identified, mapped, or protected.

Shortgrass Prairie Landowner Incentive Program to provide landowners with payments for maintaining or increasing prairie dog (*Cynomys* spp.) colonies on private lands in Baca, Pueblo, and Weld counties (Gillihan et al. 2004a). In 2001, the Rocky Mountain Bird Observatory (RMBO) began conducting an on-the-ground conservation project for ferruginous hawks in the Great Plains. This effort consists of breeding population surveys using section-based monitoring in portions of Colorado, Kansas, and Nebraska (Sparks et al. 2005). The majority (>70 percent) of the Great Plains are privately owned; therefore, this project also entails outreach to private landowners to inform them of the ecological role and conservation needs of ferruginous hawks. In addition, RMBO personnel locate nests to determine their security and, where appropriate, install cribs to protect nest trees from damage by livestock. RMBO also partners with state and federal agencies and other non-governmental organizations to find and protect nest sites (Gillihan et al. 2004a).

Olendorff (1993) and Gillihan et al. (2004a) suggested several management techniques that may benefit the ferruginous hawk in the Great Plains, including Region 2. The breeding season is a sensitive period in the life cycle of the ferruginous hawk (Gillihan et al. 2004a); therefore, management activities aimed at conservation have tended to focus on this period.

The Breeding Bird Survey (BBS) is the primary monitoring effort for the ferruginous hawk in Region 2, but it fails to provide the necessary information for appropriate monitoring of breeding populations (Gillihan et al. 2004a). Because it is sparsely distributed and BBS survey routes cover only limited portions of the species' range in Region 2, ferruginous hawks have very low detection rates, leading to analysis of population trends that lack statistical rigor. An expanded monitoring effort for ferruginous hawks is needed, focused on breeding success, total population size, distribution on the breeding and wintering grounds (especially areas of concentration), migration routes, and migratory stopover sites (Gillihan et al. 2004a). The RMBO effort described above is intended to provide reliable long-term information regarding ferruginous hawk breeding population trends and distribution within much of Region 2, which the BBS fails to provide. However, Sparks et al. (2005) estimated a period of up to 24 years to reliably detect breeding population trends, and the effort only addresses population trends during one stage in the annual life cycle of the ferruginous hawk.

Biology and Ecology

General description

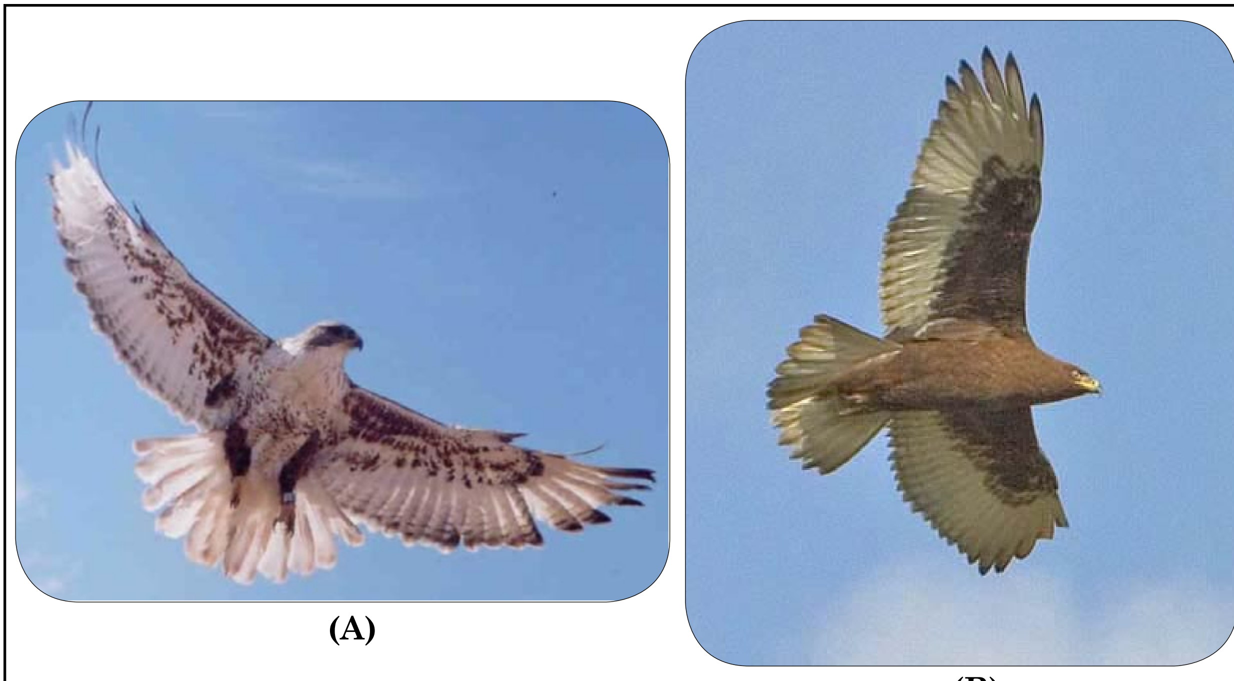
The ferruginous hawk is a member of the Order Falconiformes: Family: Accipitridae, and it is also known as Chap-hawk, eagle hawk, ferruginous rough-legged hawk, gopher hawk, or squirrel hawk (Terres 1956). Bent (1937) described the ferruginous hawk as "the largest, most powerful, and grandest of our buteos, a truly regal bird." Total length of the ferruginous hawk ranges from 59 to 69 cm (23 to 27 inches), and body mass from 977 to 2,074 g (2.2 to 4.6 lb.). As in all diurnal raptors, sexual dimorphism is apparent, with female ferruginous hawks tending to have larger bill length, gape, wing length, wing area, third toe, grasp size (center tarsal pad to tip of third toe claw), and body mass compared to males (Bechard and Schmutz 1995).

Appearance is variable due to the existence of light and dark color morphs (**Figure 2**). Light morphs are most numerous, varying in frequency from 90 to 100 percent (Bechard and Schmutz 1995). In basic plumage, light morph ferruginous hawks are distinguished from dark morphs and other North American *Buteos* by the whitish head, white or gray tail and nearly white underparts, interrupted by sparse rufous or gray specks on the belly and the characteristic rufous "V" formed by the dark legs stretched backward under the light rump in flight (**Figure 2A**; Bechard and Schmutz 1995). Dark morph ferruginous hawks are distinguished by light-colored tail and upper and lower surfaces of primaries, with dark head, body, upper and underwing surfaces, and tail coverts (**Figure 2B**; Clark and Wheeler 1987). A red-phase is similar to the dark-phase, but more rufous (Brown and Amadon 1968). Both color morphs exhibit variation. Light morphs display varying amounts of ferruginous and light gray in a band across the belly and underside of wings (Smithe 1975) while dark morphs vary in the amount of dusky brown and ferruginous pigmentation in ventral body feathers (Bechard and Schmutz 1995).

Taxonomy and systematics

In 1844, the name *Buteo regalis* was given to a ferruginous hawk specimen collected prior to 1841, by G.R. Gray (Sharpe 1874). No subspecies have been described. Based on chromosome shape and size, the ferruginous hawk is most closely related to gray hawk (*B. nitidus*), red-tailed hawk (*B. jamaicensis*), rough-legged hawk (*B. lagopus*), white-tailed hawk (*B. albicaudatus*), roadside hawk (*B. magnirostris*), and Harris' hawk (*Parabuteo unicinctus*), and it is less closely related to Swainson's hawk (*B. swainsonii*), common buzzard (*B. buteo*), and broad-winged hawk (*B. platypterus*) (Schmutz et al. 1993). The upland buzzard (*B. hemilasius*) of central Asia is similar in size to the ferruginous hawk and occupies a similar ecological role, suggesting a close taxonomic relationship dating to the Alaska-Siberia land bridge (Olendorff 1993).

Two subpopulations of ferruginous hawk, separated by the Rocky Mountains, have been proposed (Gossett 1993). Adult females east of the Rocky Mountains tend to have a longer third toe, longer bill, and wider gape than females west of the Rocky Mountains. No differences in adult males were detected between the two subpopulations (Gossett 1993).



(A)

(B)

Figure 2. (A) Light morph ferruginous hawk. Photograph by Alejandro Bravo in Janos, Mexico, used with permission). (B) Dark morph ferruginous hawk. Photograph by ©Mark Chappell, used with permission.

Current and historical distribution and abundance

Breeding season

Although the ferruginous hawk has the smallest breeding range of any North American *Buteo*, it is widely distributed throughout western North America during the breeding season, from southern Canada (Semenchuk 1992), between the Great Plains and Rocky Mountains, to northern Arizona and New Mexico (Olendorff 1993), and in the Columbia River Basin of eastern Oregon (Gilligan et al. 1994) and southeastern Washington (**Figure 3**).

The ferruginous hawk broadly occupies areas where it was reported in historical times (Coues 1877, Decker and Bowles 1926, Jewett 1926, Bowles and Decker 1931) although its range has retracted at the periphery in Alberta, Saskatchewan, and Manitoba (Bechard and Schmutz 1995). Breeding has been documented in 17 states and three Canadian provinces although it is rare in California (Small 1994) and British Columbia (**Figure 4**; Campbell et al. 1990).

Because of the lack of consistent and accurate inventory and monitoring, range-wide breeding population estimates are variable, ranging from 5,842 to 11,330 individuals (Olendorff 1993) to over 14,000 (Schmutz 1987c) in the Great Plains alone. Although several authors (Woffinden 1975, Oakleaf 1976, Powers and Craig 1976, Evans 1982, Schmutz 1984, 1987a, 1987b, 1991, Schmutz et al. 1984, Bechard et al. 1986, Moore 1987, Smith 1987, Call 1988, 1989, Woffinden and Murphy 1989, Herron 1989, 1990 and 1991, Ure et al. 1991) suggest a range-wide decrease in breeding distribution and abundance, none have provided an estimate of percent range-wide declines.

The primary reasons for apparent declines in ferruginous hawk breeding distribution and abundance, especially in Canadian provinces, is the conversion of prairie to agriculture, and invasion of aspen (*Populus tremuloides*) into areas that were formerly

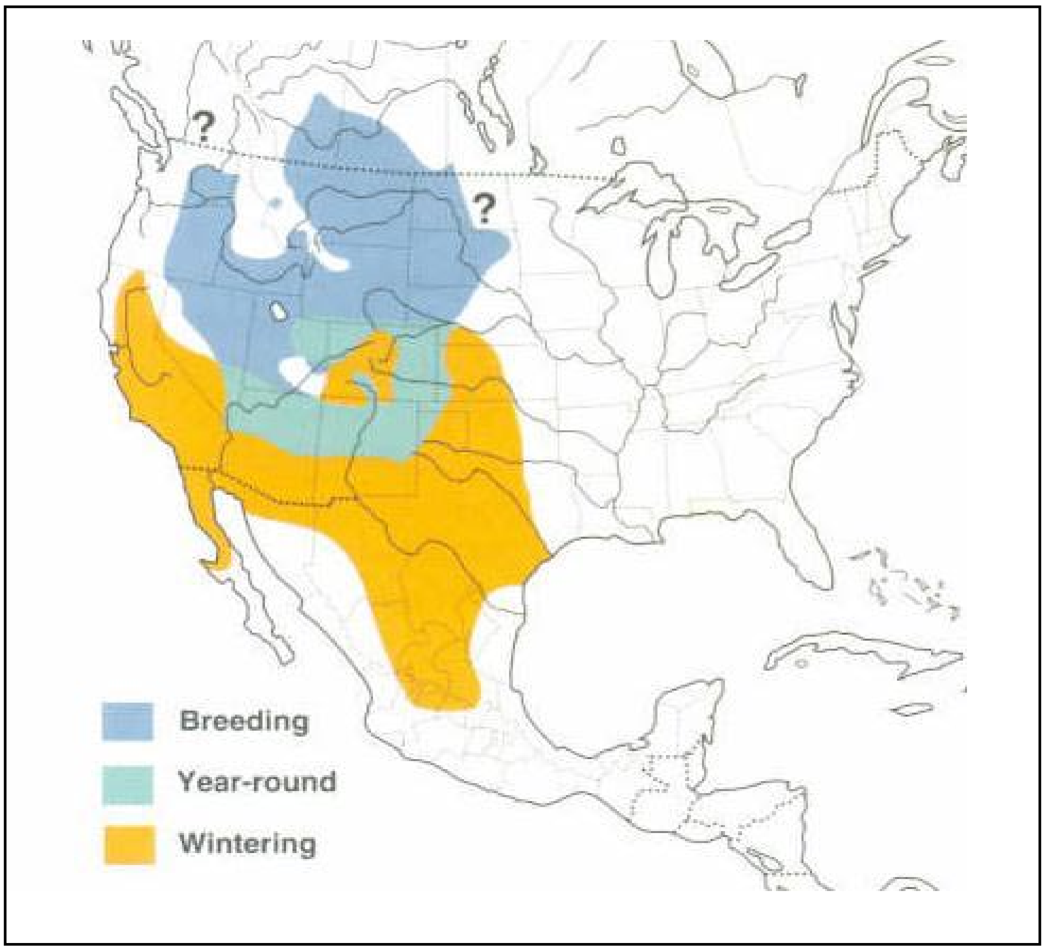


Figure 3. Distribution of the ferruginous hawk (from Bechard and Schmutz 1995).

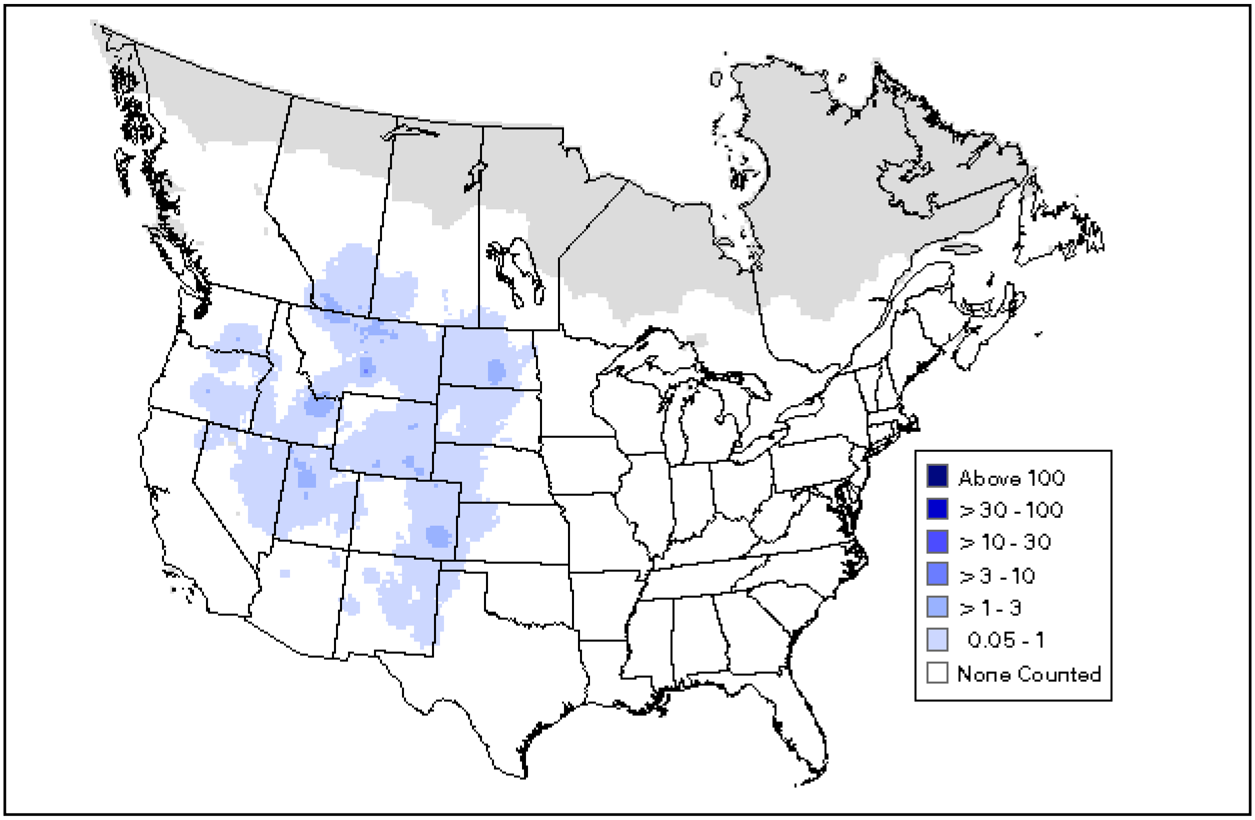


Figure 4. Current distribution and abundance of the ferruginous hawk during the breeding season, based on Breeding Bird Survey data (number of individuals per survey route, averaged over the period 1994 to 2003; Sauer et al. 2003). Figure provided for general reference only. See concerns in Population Trends section regarding the reliability of this data for ferruginous hawks.

grassland (Olendorff 1993). Woffinden and Murphy (1989) suggested that the decline in ferruginous hawk breeding abundance in northern Utah was due in part to the relative absence of a secondary prey species. When the primary prey, black-tailed jackrabbits (*Lepus californicus*), became rare, remaining ferruginous hawks became nomadic and relocated to more favorable areas to nest (Woffinden and Murphy 1989). This may also explain why other authors have reported dramatic increases over short time periods in the abundance of ferruginous hawks in Alberta (Schmutz 1987b), North Dakota (Gilmer and Stewart 1983), and Wyoming (Platt 1986).

Winter distribution

In winter, ferruginous hawks are most common in the United States from southern California, Colorado, Arizona, and New Mexico, to northern Texas (**Figure 5**; Salt 1939, Harmata 1981, Gilmer et al. 1985, Schmutz and Fyfe 1987, Warkentin and James 1988, Thompson and Ely 1989, Andrews and Righter 1992, Harmata et al. 2001), with regular but extremely local occurrences north to central South Dakota, Wyoming, southern Idaho, and Oregon (Bechard and Schmutz 1995). As much as 20 percent of the winter range may be in the Mexican portion of the Great Plains (**Figure 3**; Bechard and Schmutz 1995), where little is known of their distribution and abundance (Harmata et al. 2001, Gillihan et al. 2004a). The current winter distribution is not thought to be different from historical winter distribution (Gillihan et al. 2004a); changes in abundance from year to year may reflect changing distributions of prey populations.

Maps of estimated or predicted ferruginous hawk occurrence or habitat occurrence, produced by the National Gap Analysis Project, are provided for Colorado, Kansas, South Dakota, and Wyoming (Appendix A). Nebraska has not yet completed a GAP distribution for the ferruginous hawk. Within Region 2, the ferruginous hawk breeds and winters in every state:

Colorado

Breeding range: There are an estimated 300 active nests throughout the state (Gillihan et al. 2004a). The ferruginous hawk breeds throughout the shortgrass

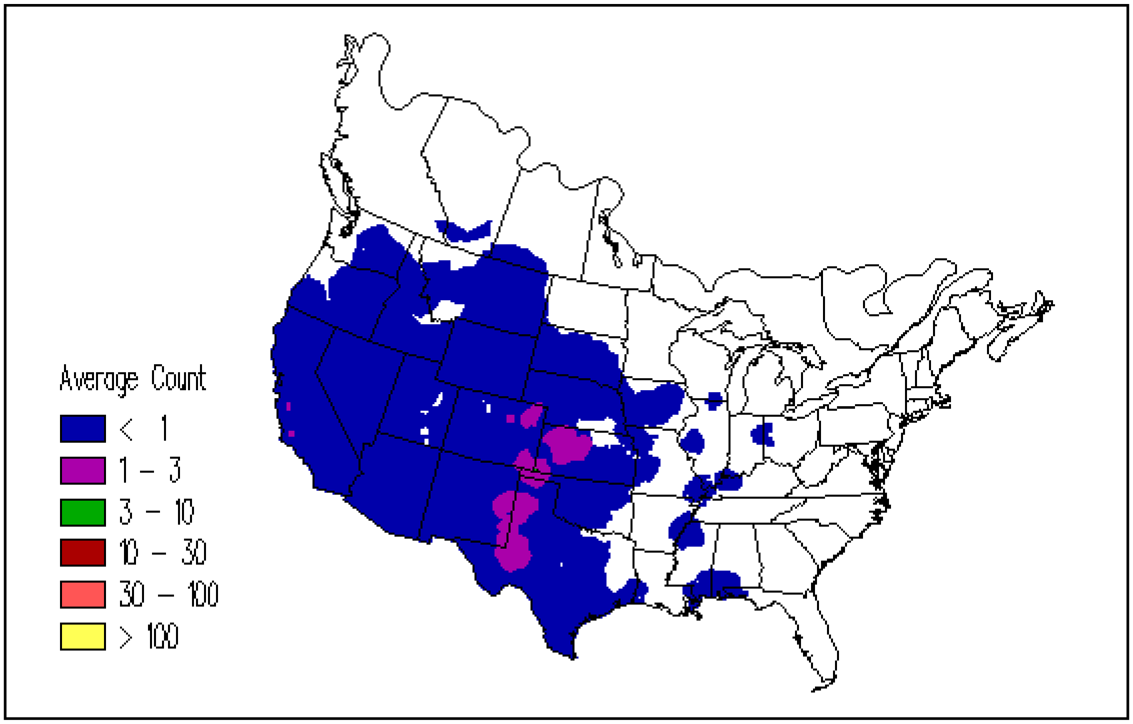


Figure 5. Distribution and abundance of ferruginous hawks during winter, based on Christmas Bird Count data (number of individuals per 100 party-hours, averaged over the period 1966 to 1989; Sauer et al. 1996). Figure provided for general reference only. See concerns in Population Trends section regarding the reliability of this data for ferruginous hawks.

prairie of the eastern half of the state, and a small number of breeding pairs occur in the northwestern corner of the state (**Figure 4**). The largest populations are found on Pawnee National Grassland in the northeast, Comanche National Grassland in the southeast, and in Washington and Yuma counties in the far northeast (Gillihan et al. 2004a). Within the Pawnee National Grassland, a small breeding population has ranged between four and 16 (Leslie 1990, 1992, Gillihan et al. 2004a) pairs since 1981, with the overall number of breeding pairs probably in decline (Gillihan et al. 2004a). Olendorff (1975) reported 26 laying pairs (a pair that lays at least one egg) within Pawnee National Grassland and provided a density estimate of one pair per 99.6 km^2. Within the Comanche National Grassland, 15 to 20 breeding pairs are present in a given year (Gillihan et al. 2004a).

Winter range: The ferruginous hawk is common during winter throughout the eastern half of Colorado (**Figure 5**), with the northern extent of its range limited by the severity of the winter (Andrews and Righter 1992). The highest winter densities occur in the area of Comanche National Grassland in the southeast, and the northeast corner of the state, including Pawnee National Grassland.

Kansas

Breeding range: The statewide breeding population is estimated between 40 and 50 pairs and has been stable for many years (Gillihan et al. 2004a). The ferruginous hawk is on the edge of its current range in Kansas. Only one healthy population is found in the northwestern part of state, along the Smoky Hill River (Roth and Marzluff 1989, Busby and Zimmerman 2001). Roth and Marzluff (1989) noted that this was the area of highest ferruginous hawk density (1 pair per 71.5 km^2) during the breeding season. A single breeding pair occurs on the Cimmaron National Grassland in extreme southwestern Kansas (Gillihan et al. 2004a).

Winter range: The ferruginous hawk is locally common during winter in the western portion of the state (Gillihan et al. 2004a). In Finney County, as many as 14 ferruginous hawks have wintered near prairie dog towns (Herbert 1987).

Nebraska

Breeding range: The estimated statewide breeding population of ferruginous hawks is typically 30 to 40 pairs, which breed locally in the northern and western third of the state (Sharpe et al. 2001). Most known nests occur in Kimball, Box Butte, Dawes, and Sioux counties (Gillihan et al. 2004a), with a few nests documented in the southwest (Mollhoff 2001). The greatest density of ferruginous hawks in Nebraska is on the High Plains and Smoky Hills physiographic regions (Busby and Zimmerman 2001).

Winter range: The ferruginous hawk is a regular but uncommon winter inhabitant in central and western Nebraska (Sharpe et al. 2001).

South Dakota

Breeding range: The ferruginous hawk breeds throughout the state, excluding the southeastern corner, but it is most heavily concentrated in the north-central portion, east of the Missouri River (Peterson 1995). At least 100 confirmed breeding locations are known, with another 20 probable sites and 50 possible breeding sites reported (Peterson 1995). Olendorff (1993) estimated 350 to 375 pairs in the entire state.

Winter range: Ferruginous hawks frequently winter in the southern parts of South Dakota, and they may winter farther north during mild winters (Steenhof 1984, South Dakota Ornithologists' Union 1991, Tallman et al. 2002). Up to six individuals were reported at one roost site (Steenhof 1984).

Wyoming

Breeding range: Wyoming is the approximate center of the ferruginous hawk breeding range and has one of the largest breeding populations of any state or province (Olendorff 1993). Oakleaf (in Call 1985) estimated more than 800 pairs of ferruginous hawks in the state. The ferruginous hawk breeds throughout most of Wyoming, excluding the northwestern corner, with the highest nesting densities found in the Shamrock Hills of Carbon County (Call 1988, 1989).

Winter range: Ferruginous hawks are found locally during winter in extreme southern Wyoming (Bechard and Schmutz 1995).

Population trends

Recent estimates of range-wide ferruginous hawk numbers are quite variable, ranging from 5,842 to 11,330 (Olendorff 1993) individuals in the entire population to 14,000 individuals in the Great Plains alone (Schmutz 1987d). Although no range-wide data are available, the ferruginous hawk is thought to be declining in overall numbers (Evans 1980, 1982). The best documentation of declining breeding numbers is found in southern Saskatchewan (40 percent of historic range not occupied, another 40 percent sparsely occupied; Houston and Bechard 1984, Smith 1987), Alberta (40 percent decrease in distribution; Schmutz et al. 1980, Schmutz 1984, 1987a, 1987b, 1987c, 1989a, 1989b, Moore 1987), and Manitoba (100 percent decrease in distribution for a 57-year period; Bechard 1981, De Smet and Conrad 1991). Reported percent declines in Canadian provinces should be viewed with caution because historical reports of ferruginous hawk distribution were anecdotal in nature. Stewart (1975) reported the near extirpation of the ferruginous hawk from northeastern North Dakota, and extirpation of a local Utah population was reported by Woffinden and Murphy (1989). Olendorff (1993) suggested that a recovery of Canadian populations to historical numbers is unlikely because historical conditions no longer exist. The application of pesticides, a well-documented reason for declines of other raptor populations, does not appear to be related to any ferruginous hawk declines (Stendell et al. 1988).

A decline in abundance in the core breeding range throughout the 1980s was suggested by vacancy of many historic nest sites; however, population increases of at least 50 percent have been documented in the past 20 years in Oregon, Wyoming, Alberta, and Manitoba (Bechard and Schmutz 1995). Declines in ferruginous hawk numbers in certain parts of its range and concomitant increases in other areas suggest that ferruginous hawks adapt to local fluctuations in prey populations. Abundance of breeding pairs of ferruginous hawks has been significantly correlated with abundance of prey populations in central Utah (Smith and Murphy 1978, Woffinden and Murphy 1989), Alberta (Schmutz and Hungle 1989), and New Mexico (Cook et al. 2003). In addition, a decline in abundance of migrating and wintering ferruginous hawks was correlated with loss of prairie dogs in Colorado and New Mexico (Cully 1991, Seery and Matiatos 2000). These studies indicate that accurate determination of ferruginous hawk population trends can be complicated by nomadism, and that apparent regional and local population trends, when assessed independently or collectively, may not accurately reflect range-wide population trends.

Breeding Bird Survey data indicate a significant (P <0.01, N = 240 routes) survey-wide positive trend of 2.9 percent per year for the period from 1966 to 2003 (**Table 2**; Sauer et al. 2003). However, because

Table 2. Region 2 population trends (average percent change per year) for ferruginous hawk from Breeding Bird Survey data for 1966 to 2003 (Sauer et al. 2003). Data provided for general reference only. See concerns in text regarding the reliability of this data for ferruginous hawks.

	1966 – 2003			1966 – 1979			1980 – 2003		
Area	**Trend**	***P*-value**	**N Routes**	**Trend**	***P*-value**	**N Routes**	**Trend**	***P*-value**	**N Routes**
Colorado	2.4	0.29	33	7.1	0.27	7	4.9	0.11	32
Kansas	-7.0	0.14	6	No data			-20.6	0.22	4
Nebraska	3.9	0.73	6	No data			7.7	0.85	5
South Dakota	10.3	0.29	12	71.1	0.06	4	6.5	0.62	11
Wyoming	1.4	0.65	46	-16.3	0.05	5	-2.5	0.51	42
United States	2.6	0.02	211	5.3	0.11	28	1.2	0.38	198
Canada	4.9	<0.01	29	11.1	0.39	4	2.1	1.41	27
Survey-wide	2.9	<0.01	240	6.2	0.06	32	1.4	0.28	225

ferruginous hawks occur at low densities (i.e., a mean of 0.25 ferruginous hawks per route) and are often difficult to detect, these trend data are not reliable (Sauer et al. 2003). Christmas Bird Count (CBC) data indicated a significant (P <0.01, N = 383 count circles) survey-wide positive trend of 3.9 percent per year from 1959 to 1988 (Sauer et al. 1996), but the very low (mean = 0.28 ferruginous hawks per 100 party hours) relative abundance of ferruginous hawks casts doubt on the significance of winter population trends.

Within Region 2, only Wyoming exhibited a statistically significant (P = 0.05, N = 5 routes) trend during any time period (1966 to 1979) during the BBS survey history (**Table 2**). However, the small sample size and low abundance (mean = 0.50 ferruginous hawks per route) of ferruginous hawks cast doubt on the significance of the trend. Only Colorado and Kansas had CBC data available (**Table 3**), and although Colorado exhibited a significant population trend from 1959 to 1988 (Sauer et al. 1996), the low (mean = 0.60 ferruginous hawks per 100 party hours) relative abundance of ferruginous hawks makes trend interpretation unreliable.

An additional method used to track raptor population trends is through counts of migrating raptors along routes where they concentrate. Between 1977 and 2001, Hawkwatch International conducted such counts at six locations located along the Rocky Mountain Flyway, one of three major flyways used by migrating raptors in the western United States (Hoffman and Smith 2003). Although not all six sites were operated for the entire period, analysis of count data indicated that four of the six sites exhibited a significant decrease in abundance of migrating ferruginous hawks (Hoffman and Smith 2003). Hoffman and Smith (2003) noted that these results correlated with western North America CBC data for the same period, but they were in opposition to BBS data for 1977 to 2001. The disparate trend indicators may have reflected the nomadic lifestyle of the ferruginous hawk (Hoffman and Smith 2003). Because ferruginous hawks migrate on a broad front and may exhibit a strong nomadic tendency during annual migration, it is difficult to use migration counts to infer significant population increases or declines (Hoffman and Smith 2003, Watson 2003).

Table 3. Region 2 population trends (average percent change per year) for the ferruginous hawk from Christmas Bird Count data for 1959 to 1988 (Sauer et al. 1996). Data provided for general reference only. See concerns in text regarding the reliability of this data for ferruginous hawks.

	1959 - 1988		
Area	Trend	*P*-value	N Count Circles
Colorado	4.6	<0.01	27
Kansas	3.3	>0.10	20
Nebraska	No data		
South Dakota	No data		
Wyoming	No data		
Survey-wide	3.9	<0.01	383

Range-wide and Region 2 annual variation in ferruginous hawk breeding numbers is primarily influenced by changes in prey abundance while annual variation in winter abundance of ferruginous hawks is primarily related to winter severity and prey abundance. In milder and normal winters, ferruginous hawks are common in eastern Colorado (Andrews and Righter 1992), locally common in western Kansas (Gillihan et al. 2004a) and southern South Dakota (Steenhof 1984, South Dakota Ornithologists' Union 1991), regular but uncommon in central and western Nebraska (Sharpe et al. 2001), and local in extreme southern Wyoming (Bechard and Schmutz 1995). In more severe winters, ferruginous hawk numbers may be severely reduced in South Dakota (Steenhof 1984, South Dakota Ornithologists' Union 1991) and Wyoming.

Activity patterns

Circadian, seasonal and annual activity patterns

Circadian patterns: Ferruginous hawks are a diurnal species and probably do not move at night. However, no one has attempted to investigate this assumption through radiotelemetry or other means. Observational studies at ferruginous hawk nests in Utah (Wakeley 1974, Smith and Murphy 1978) indicate that ferruginous hawks exhibit a bi-modal pattern of hunting activity, the first from shortly after first light to mid-morning (0600 - 0900), and the second from late afternoon to shortly before darkness (1700 - 2100). Bloom et al. (1992) suggested that bimodal circadian activity patterns of ferruginous hawks are influenced by the activity patterns of their prey. Ferruginous hawk populations that prey primarily on lagomorphs, which are crepuscular, tend to show a crepuscular hunting pattern, while populations that prey primarily on ground squirrels (*Spermophilus* spp.), which are diurnal, do not. Bechard and Schmutz (1995) reported that ferruginous hawks are generally more vocal in morning and late afternoon.

Seasonal and annual activity patterns: Ferruginous hawks display an annual activity pattern similar to other migrant or partial migrant raptors (**Figure 6**). The breeding season begins in mid-March and ends in mid-August when the young become fully

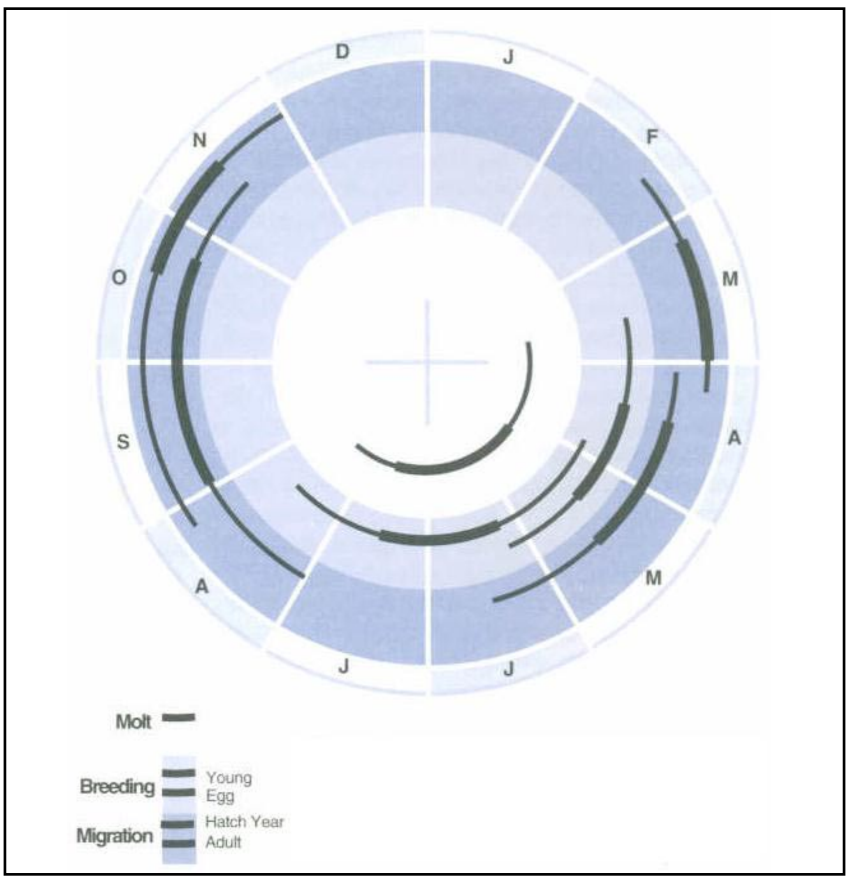


Figure 6. Mean range-wide timing of life-cycle events of the ferruginous hawk. Thick lines show peak activity, thin lines off-peak activity (adapted from Bechard and Schmutz 1995).

independent (see Breeding biology section). The timing of migration can vary with latitude, bird age, and gender (**Figure 6**; see Migration section).

Broad-scale movement patterns

Several types of animal movement applicable to ferruginous hawks have been recognized. *Migration*, as used in this assessment, is the regular, annual movement of individuals between specific breeding and non-breeding ranges. Dispersal, as used in this assessment, consists of two types: *Breeding dispersal* is the movement of breeding individuals among breeding sites between years; *Natal dispersal* is the movement of an individual from its natal area to its first breeding area. *Nomadism*, as used in this assessment, is movement related to abrupt increases or declines in food abundance in which individuals do not follow a regular migration pattern to return to specific areas where they bred or wintered in previous years, but rather, wander widely in search of suitable food supplies necessary for breeding or winter survival.

Migration: Ferruginous hawks display different migration patterns depending on the latitude of the breeding population. Northern populations breeding in Washington, Montana, North Dakota, and Alberta are completely migratory (Call 1979, Schmutz and Fyfe 1987, Bechard and Schmutz 1995). Little is known about the migration patterns of populations in southern portions of the breeding range (Bechard and Schmutz 1995), which are thought to be sedentary throughout the year or to migrate only short distances (Bechard and Schmutz 1995, Gillihan et al. 2004a).

The timing of migration depends on latitude and bird age. Northern populations begin spring and fall migrations earlier than southern populations. Most adults in northern populations begin southward migration in late September or early October while most sub-adults depart in August or early September; all individuals in Alberta had departed the breeding range by late October (Schmutz and Fyfe 1987). Hatch-year birds migrate independently of their parents and nest-mates (Woffinden and Murphy 1983, Schmutz and Fyfe 1987, Watson 2003). Adults in northern breeding populations begin northward migration in late February or early March, earlier than sub-adults, which begin to migrate in early or mid-April. Populations in the northern portions of Region 2, especially South Dakota and Wyoming, are probably mostly migratory, based on the greater abundance of ferruginous hawks during the breeding season compared to winter. The exact timing of migration of northern populations is also related to activity patterns of prey. Ferruginous hawks in Alberta were reported to begin southward migration at the time their primary prey, Richardson's ground squirrels (*Spermophilus richardsonii*), entered estivation (Schmutz and Fyfe 1987). Ferruginous hawk populations in the southern portions of Region 2 are probably partially to completely sedentary, but it is not known whether all resident breeding individuals are sedentary and, if not, what percentage undertake migration.

The timing and pattern of ferruginous hawk migration may also be influenced by gender (Watson 2003). In Washington, Watson (2003) suggested that female ferruginous hawks needed to replenish fat stores depleted through egg-laying and incubation, and initiated migration almost immediately after young had fledged. These females migrated directly to ground squirrel and prairie dog colonies east of the Rocky Mountains. In contrast, males remained on breeding territories to feed fledged young after females had departed on migration, an advantage in maintaining a breeding territory. Specific migration routes of ferruginous hawks are probably established through exploration and learning as juveniles, rather than reliance on innate cues (Watson 2003).

Within Region 2, most ferruginous hawks return to breeding areas in South Dakota in late March or early April (Lokemoen and Duebbert 1976), and late February or early March in northeastern Colorado (Olendorff 1973). Information is lacking regarding the migratory status of ferruginous hawks in Kansas, Nebraska, and southern Colorado, but populations in these areas are probably sedentary or only partially migratory. No studies have specifically examined the relationship between the onset or severity of inclement weather and their effects on initiation of southward migration.

The migration routes of ferruginous hawks banded in Alberta (Salt 1939, Schmutz and Fyfe 1987), Colorado (Harmata 1981), and North Dakota (Gilmer et al. 1985) generally follow grasslands, likely because of available prey resources (Schmutz and Fyfe 1987). Eastern and western subpopulations on either side of the Continental Divide were generally believed to migrate on their respective sides of the Divide. However, Thurow et al. (1980) proposed a migratory gap in southeastern Idaho, allowing mixing of the two subpopulations. Examination of 537 band recoveries showed 4.1 percent of eastern birds were recovered west of the Continental Divide and 27.5 percent of western birds were recovered east of the Divide (Gossett 1993). Overall crossover was 8.6 percent. It is unknown why more western birds appeared to cross the Divide than vice versa, but it is possible that eastern winter range provides a more consistent food supply. In addition, nine of 10 ferruginous hawks marked in Washington migrated across the Divide, and six of those returned west of the Divide later in the winter (Watson and Pierce 2000). These studies indicate that eastern and western subpopulations are not disjunct, and that significant mixing of the two subpopulations probably occurs on a regular basis. However, Watson and Banasch (2004) reported that hawks banded in distinct wintering areas in Mexico reflected distinct United States/Canadian breeding populations, and each breeding population appeared to use distinct migration corridors. Populations wintering in north-central Mexico nested in the Great Basin (Arizona, Utah, and Nevada) while those wintering in northeastern Mexico nested in the Central Plains (Colorado and Wyoming). The latter population consistently migrated along grasslands on the eastern side of the Rocky Mountains while the former crossed the Continental Divide to reach breeding areas. Ferruginous hawks have been reported to display a high degree of philopatry to wintering areas (Plumpton and Anderson 1997, Watson 2003).

Breeding and natal dispersal, and nomadism: Breeding dispersal in ferruginous hawks is often influenced by nest success the previous year (Dechant et al. 1999). In Manitoba, 52 percent of 71 successful nests were reused, compared to 14 percent of 63 unsuccessful nests (De Smet 1992). However, Smith and Murphy (1973) reported that breeding pairs in Utah were more prone than other raptors to choose a different nest site in consecutive years, and did so 75 percent of the time, although most of these movements to different nest sites were within the same territory, and nests were often located very near previous years' nests. It is likely that the extent of breeding dispersal is affected by nomadism, with much longer distances between breeding sites in consecutive years when breeding hawks display nomadism due to reduced prey abundance. The extent of nomadism exhibited by various populations of ferruginous hawks is unknown. No information is available regarding the nature of natal dispersal in ferruginous hawks.

Habitat

Range-wide, ferruginous hawks occupy a variety of habitat types including open grasslands, shrub-steppe, croplands, desert, and the periphery of western pinyon (*Pinus eulis*) – juniper (*Juniperus* spp.) woodlands (Jasikoff 1982, Gilmer and Stewart 1983, Olendorff 1993, Bechard and Schmutz 1995). Dense forests, extensive aspen parklands, high elevations, narrow canyons, and habitats recently altered by human development or cultivation are avoided (Janes 1985, Palmer 1988, Black 1992, Olendorff 1993, Bechard and Schmutz 1995). Of all the large raptors, the ferruginous hawk is second only to the red-tailed hawk in the array of habitats used (Cottrell 1981, Knight and Smith 1982). In general, the fundamental habitat difference between eastern and western subpopulations of ferruginous hawks is the predominant use of shrub-steppe west of the Continental Divide and grasslands east of the Divide (Bechard and Schmutz 1995). The chief habitat requirement of ferruginous hawks, regardless of vegetation type, is an adequate supply of small rodents, their primary food source (Weston 1969).

Breeding habitat

Breeding habitat includes nesting, post-fledging, and foraging areas, and includes all of the above habitat types. Within each broad category of ferruginous hawk habitat, smaller scale features are important for successful reproduction. Sparse riparian forests, the periphery of forests, terrain features such as cliffs, rolling hills and rock outcrops, isolated trees and small groves provide habitat diversity and increased suitability for nesting ferruginous hawks (Smith and Murphy 1973, Woffinden 1975, Lokemoen and Duebbert 1976, Cottrell 1981, Roth and Marzluff 1989, Restani 1991, Olendorff 1993).

Nest site and nesting area: Nest sites, or the actual physical location of nests chosen by ferruginous hawks, are variable throughout the breeding range (Bechard and Schmutz 1995). Of 2,119 nests described throughout this species' range, most (49 percent) were located in trees and shrubs, followed by cliffs (21 percent), utility structures (12 percent), on the ground or dirt outcrops (15 percent), haystacks (3 percent) and buildings (less than 1 percent) (Olendorff 1993). Olendorff's (1993) estimates do not include studies where artificial nesting structures designed specifically for raptors were used. Artificial nesting platforms have become important nest sites in habitats lacking natural nest sites within otherwise suitable nesting habitat (Anderson and Follett 1978, Howard and Hilliard 1980, Houston 1982, Schmutz et al. 1984; see Population management tools section). Juniper is the most commonly used tree for nesting, especially in the juniper forest/shrub-steppe interface in states west of the Continental Divide. Ferruginous hawks have also used pine, willow, cottonwood, and sagebrush.

When nests are not placed on the ground, they are usually constructed 2 to 8 m (6 to 24 ft.) above ground (Weston 1969, Bechard et al. 1990, Restani 1991), but they may be as high as 20 m (60 ft.), especially on electrical transmission towers (Bechard and Schmutz 1995). Historically, ground nesting may have been more common, especially on the Great Plains, which exhibit a paucity of trees. However, post-Euro American settlements, fire suppression, planting of shelterbelts, and abandonment of treed homesteads have increased the availability of trees for nesting (Gillihan et al. 2004a).

Nesting pairs exhibit selection for nest site characteristics within the larger habitat matrix (Cottrell 1981). In northeastern Oregon, Cottrell (1981) reported that ferruginous hawks did not utilize habitat features in proportion to availability, preferring to locate their nests on south-facing rock outcroppings, lone pines on northern exposures, or in aspen groves. They avoided scablands, pine groves, and cultivated lands. Roth and Marzluff (1989) reported three apparent instances of nest site selection in Kansas: 1) a preference for ledge sites relative to ground sites, 2) a preference for rangeland relative to cropland, and 3) a preference for inaccessible (to quadrupeds) sites relative to accessible sites. An important characteristic of nest sites, regardless of habitat type, is their spatial relationship to food supplies (Smith and Murphy 1973). Cook et al. (2003) reported a positive spatial association between nests and prairie dog towns in New Mexico.

Although ferruginous hawks tend to avoid cultivated areas for nesting (Olendorff and Stoddart 1974, Blair 1978, Cottrell 1981, Gilmer and Stewart 1983, Schmutz 1984, 1989a, Bechard et al. 1990), they can breed successfully in lightly to moderately (less than 10 to 30 percent) cultivated areas. Schmutz (1989a) reported an increasing relationship between ferruginous hawk breeding density and cultivation up to 30 percent; hawk density decreased at cultivation amounts greater than 30 percent. The explanation for avoidance of highly (>30 percent) cultivated areas is that prey densities or prey availability (through excellent concealment cover of many monotypic crops) may decrease as agriculture increases. In addition, suitable nest trees become scarce in highly cultivated areas, and disturbance by farmers increases.

Nesting areas (a geographic region inhabited by no more than one pair of ferruginous hawks at a time [Roth and Marzluff 1989]) often contain multiple alternate nests. In Kansas, nesting areas ranged in size from 0.01 to 1.00 km^2 and contained up to eight alternate nests (Roth and Marzluff 1989). Nesting areas comprise a relatively small fraction of the entire breeding home range. Average breeding home range sizes of ferruginous hawks in Utah, Oregon, and Idaho ranged from 3.4 to 9.0 km^2 (Smith and Murphy 1973, Janes 1985). However, these home range estimates were derived from visual observations and may not be as accurate as estimates derived from radiotelemetry studies, which have not been reported in the literature.

Jasikoff (1982) produced a Habitat Suitability Index model for the ferruginous hawk, which focused on breeding habitat suitability. He suggested that habitat alteration due to cultivation and direct human disturbance to breeding pairs are the two factors most responsible for unsuccessful breeding of ferruginous hawks. Several observers (Weston 1968, Olendorff 1973, Olendorff and Stoddart 1974, Fyfe and Olendorff 1976, Lokemoen and Duebbert 1976, Blair 1978, Jasikoff 1982, Roth and Marzluff 1989, Bechard et al. 1990) reported that ferruginous hawks avoid human disturbance when selecting nest sites, and that they are particularly sensitive to disturbance during courtship, egg-laying, and incubation. Thus, a critical component of any suitable nesting habitat is freedom from human disturbance during these time periods.

In summary, breeding habitat should contain four primary characteristics (Gillihan et al. 2004a):

- ❖ adequate availability and security of nest substrates
- ❖ lack of disturbance to nesting pairs
- ❖ an adequate prey base
- ❖ suitable habitat surrounding nest sites.

Wildlife managers have some degree of control over all of these factors; therefore, the potential exists to improve breeding habitat where it is deemed less than suitable (see Habitat management tools section).

Migration and wintering habitat: Little information is available regarding migration habitat of ferruginous hawks. However, the preference of ferruginous hawks for grasslands during the breeding season is also displayed in choice of migration habitat. Schmutz and Fyfe (1987) reported 83 percent of 135 ferruginous hawks banded during the breeding season in grasslands east of the Divide were recovered in grassland. Specific migration routes within grasslands are likely dictated by the distribution of prey resources

(Watson and Pierce 2000), especially black-tailed prairie dogs (*Cynomys ludovicianus*) and Richardson's ground squirrels east of the Rocky Mountains.

Ferruginous hawks winter in open terrain from grassland to desert (Bechard and Schmutz 1995). East of the Continental Divide, winter habitat selected by ferruginous hawks is primarily grassland, and Bak et al. (2001) found that it was directly correlated with occupied black-tailed prairie dog colonies rather than vegetation composition or structure in New Mexico and northern Mexico. In Colorado, wintering ferruginous hawks were reported to concentrate in habitats with the highest densities of prairie dogs (Plumpton and Anderson 1997, Seery and Matiatos 2000). West of the Divide, ferruginous hawks winter in grasslands and arid regions containing an abundance of prairie dogs, lagomorphs, or pocket gophers (Bechard and Schmutz 1995). Relatively undisturbed native grasslands are of primary importance to wintering populations of ferruginous hawks. However, in contrast to other times of the year, they are more likely to be found in areas containing higher cultivation (Schmutz 1987a), likely because of the greater prey densities near field edges (Zelenak and Rotella 1997). Similar to observations during the breeding season, Berry et al. (1998) reported that winter abundance of ferruginous hawks in Colorado was negatively correlated with areas where urban development exceeded 5 percent. Whether this reflects a reduced abundance of prey in urbanized areas in Colorado or the penchant of ferruginous hawks to avoid urbanized areas is unknown, but both likely play a role.

Food habits

The ferruginous hawk is somewhat of a prey specialist, relying on relatively few prey species, most of which are mammals (Thurow and White 1983, Bechard and Schmutz 1995, Cartron et al. 2004). Mammalian prey constitutes as much as 95 percent of the biomass consumed by ferruginous hawks (**Table 4**). Range-wide, lagomorphs are especially important, including jackrabbits and hares, which compose the majority of mammalian biomass consumed by ferruginous hawks. Sciurids, including ground squirrels and prairie dogs, are the most frequently captured prey item, but theses constitute a smaller portion of the total mammalian biomass consumed. Within Region 2, ground squirrels and prairie dogs were the most important prey item in six of seven studies, based on frequency of capture by ferruginous hawks (Olendorff 1973, Lokemoen and Duebbert 1976, Blair 1978, Roth and Marzluff 1984, MacLaren 1986, Stalmaster 1988, Andersen and Rongstad 1989). Prey selection is related to the availability of prey species (Steenhof and Kochert 1985). In general, sciurids are more prominent in the diet of ferruginous hawks east of the Continental Divide while lagomorphs are more prominent west of the Divide because these species are more common on

Table 4. Prey of ferruginous hawks by major animal taxa from 20 studies (adapted from Olendorff 1993).

Taxon	Sample Size	Percent Frequency	Percent Biomass
Mammals	5,166	83.3	95.4
lagomorphs	1,228	19.8	65.9
ground squirrels	2,437	39.3	17.9
prairie dogs	282	4.5	7.5
pocket gophers	492	7.9	2.6
kangaroo rats	412	6.6	0.7
other	315	5.5	0.8
Birds	822	13.2	4.1
Galliformes	39	0.6	1.6
Passeriformes	644	10.4	1.3
ducks	36	0.6	0.9
other	103	1.6	0.3
Amphibians and Reptiles	147	2.4	0.5
snakes	100	1.6	0.4
lizards	44	0.8	0.1
other	3	0.0	0.0
Insects	68	1.1	<0.1

the eastern and western sides of the Divide, respectively (Bechard and Schmutz 1995). If primary prey levels decline, ferruginous hawks may shift to alternate prey, if available. When jackrabbit and cottontail numbers declined in Wyoming, ferruginous hawks were able to persist by feeding on ground squirrels (Call 1988). In contrast, when lagomorph numbers declined in central Utah where there were few alternate prey, such as ground squirrels and prairie dogs, the local ferruginous hawk breeding population declined to near extinction through reduced productivity and nomadism (Woffinden and Murphy 1989). Many of the mammalian species upon which the ferruginous hawk depends are subject to dramatic periodic cycling of their population numbers. Therefore, in areas where alternate prey species are non-existent, ferruginous hawk population numbers are likely to display patterns synchronous with those of their primary prey.

Ferruginous hawks capture their prey using four general techniques (Wakeley 1974):

- ❖ still hunting from perches with short flights less than 100 m (328 ft.) to capture prey,
- ❖ aerial hunting from low altitudes (4.6 to 15.2 m [15 to 50 ft.]) along slopes and hillsides, and aerial hunting or soaring from altitudes >15.2 m,
- ❖ ground hunting consisting of pursuit of prey after a missed capture attempt from the air, or a "sit and wait" technique in which a hawk stands next to a rodent burrow or earthen pile and waits for prey to come close to the surface, where the hawk pounces and pulls out prey (Palmer 1988),
- ❖ hovering for several seconds, especially when in a strong wind.

Cooperative hunting has not been reported for the ferruginous hawk; however, other ferruginous hawks or golden (*Aquila chrysaetos*) and bald (*Haliaeetus leucocephalus*) eagles may displace an individual with prey. Habitat structure that is conducive to successful hunting is characterized by vegetative cover that is open enough to make prey vulnerable. Because of this, ferruginous hawks may benefit from land uses such as grazing or other practices that open dense shrubland, including partial conversion to grassland, provided the effect is not so severe as to influence the viability of the prey species.

Breeding biology

The mating system of ferruginous hawks is social monogamy. Although ferruginous hawks are also assumed to be genetically monogamous, there was a single report of possible extra-pair copulation (Schmutz and Schmutz 1981). Birds probably choose mates near their breeding territories, and some breeding pairs may maintain pair bonds throughout the year, especially in southern latitudes where winter migration is limited or non-existent.

Courtship

The courtship period is characterized by flight displays during which both birds soar in large circles at high altitudes, the male exhibiting slow, deliberate wingbeats with irregular yawing and pitching. The male also performs several dives and ascensions, after which he approaches the female from above, extends his legs, and may momentarily grasp the female (Bechard and Schmutz 1995). The pair may dangle their legs, grasp bills, and interlock talons while spiraling downward. Courtship displays are often accompanied by screams and calls. Copulations occur over a period of several days, often initiated after nest building by the male. Generally, the male also feeds the female either before or after copulation. Courtship activities related to pair bonding begin in late February to early March throughout most of the ferruginous hawk's range, but the timing of the entire breeding process may occur two to three weeks later in more northern latitudes.

Nest site selection and construction

Both members of a breeding pair share in selection of a nest site, which is characterized by visitation of multiple old nests within a breeding territory, and much perching near the chosen nest site. A pair may bring nesting materials to more than one nest within a territory. An important component of a suitable nest site is the degree of isolation from human disturbance. Ferruginous hawks were reported to nest farther from human disturbance than would be expected at random (Lokemoen and Duebbert 1976, Blair 1978) and farther from disturbances such as roads than Swainson's hawks (Bechard et al. 1990). Once a nest site is selected, both members of a pair participate in nest building or refurbishment of a previously used nest. The male delivers most nesting materials to the nest while the female primarily arranges nest materials. Nests are typically constructed of large sticks, sagebrush or yucca stems, twigs, and other debris found within the habitat surrounding the nest. Debris may include bones, dung, bailing wire, and twine; historically, rib bones of bison were commonly used in construction of ferruginous hawk nests in the Great Plains (Houston and Bechard 1984). The female commonly lines the nest bowl with dead and dry material, including leafed twigs, grass sod or stubble, bark, and forbs. Historically, nests were often lined with bison wool.

Ground nests often consist of three distinct layers: (1) the lower and outside portion of the nest is constructed of larger gauge materials such as bones and sticks, (2) the dense middle layer often contains dung and grass sod, and (3) the nest is lined with finer materials. The dense middle layer of ground nests always remains moist, which, when combined with the nest lining, creates a moist microclimate for the eggs (Lokemoen and Duebbert 1976). Tree nests usually do not contain a well-defined middle layer (Lokemoen and Duebbert 1976).

Ferruginous hawk nests are large structures, due to the tendency for nests to be re-used and enlarged in consecutive years. Nests are often greater than 1 m in outside diameter and overall height (Bechard and Schmutz 1995); therefore, sturdy supporting branches are required to support the weight of the nest if it is constructed in a tree. Artificial nesting platforms have been successfully used by ferruginous hawks in many areas, including Wyoming (Tigner et al. 1996) and Colorado (Stalmaster 1988, Olendorff 1993) within Region 2. These structures may provide more secure and stable nesting substrates, especially in areas where there is a paucity of natural nest sites.

Nest refurbishment or construction is completed in less than one week (Palmer 1988). Eggs are laid at approximately two-day intervals, and mean clutch size (two to four eggs, range one to eight eggs) is large compared to other buteos. There may be variation in clutch size, depending on prey abundance and nest substrate; clutches in ground nests in South Dakota were larger than those in tree nests (Lokemoen and Duebbert 1976). Incubation begins with the laying of the first egg and lasts 32 to 33 days, with the eggs hatching asynchronously. Most incubation is performed by the female, who takes short (less than 5 minute) breaks to receive food delivered by the male. During this time, ferruginous hawks are especially vulnerable to human disturbance (Smith and Murphy 1978, White and Thurow 1985). If interrupted, a pair may abandon nest-building activities, or an incubating female may abandon her clutch.

Young

Upon hatching, the young are altricial, typical of all *Buteos* (Bechard and Schmutz 1995). During the first three weeks after hatching, the female broods the young and depends upon the male to provide food for both her and the young. During this time, the female feeds small morsels to chicks. After three weeks, the female gradually spends more time perching on the edge of the nest or elsewhere nearby while food items are delivered by the male and left whole in the nest. The female also begins to hunt more frequently as the chicks develop beyond three weeks of age. Siblicide is rare among nestlings. However, a lack of food may induce male nestlings to abandon the nest, and older nestlings may kill younger siblings and cannibalize them to survive (Woffinden and Murphy 1977, Ensign 1983).

Nestlings leave the nest at 38 to 50 days of age, with males leaving as much as 10 days earlier than females, which are larger (Powers 1981, Konrad and Gilmer 1986, Zelenak et al. 1997). Nest substrate also affects the timing of young leaving the nest; young walk out of ground nests earlier than nestlings fledge from elevated nests (Bechard and Schmutz 1995). After fledging, the young are dependent upon their parents for several weeks (Blair and Schitoskey 1982) and remain within 200 m (660 ft.) of the nest for several days, perching on trees, elevated perches, or on the ground (Bechard and Schmutz 1995, Zelenak and Rotella 1997, Zelenak et al. 1997). During the post-hatching through post-fledging period, the parents are highly protective of the young, and they are not likely to abandon the nest or fledglings. Fledglings are able to fly well within two weeks (Bechard and Schutz 1995) and may leave the nesting area in loose sibling groups at about 28 days (Woffinden and Murphy 1982).

Nesting associates

In southeastern Alberta, Schmutz et al. (1980) demonstrated lower reproductive success when ferruginous, red-tailed, or Swainson's hawks nested in close (less than 0.3 km) proximity; they suggested competition for space was the cause. In Montana, Restani (1991) reported no decline in productivity for nests in close proximity but did document nest substrate partitioning between red-tailed and ferruginous hawks, and dietary partitioning between Swainson's hawks and ferruginous hawks. In contrast, Thurow and White (1983) suggested a mutualistic relationship between ferruginous and Swainson's hawks in Idaho. Despite an abundance of nest sites on the study area, Swainson's hawks chose to nest closer to active ferruginous hawk nests than would be randomly expected. Swainson's hawks were the ones who made this choice because ferruginous hawks arrived on the breeding areas one month earlier than Swainson's hawks. In addition, both species tolerated the others' presence and on several occasions displayed mutual defense of the others' nest. Examples included giving alarm calls when an intruder approached the nest of the other species, a Swainson's hawk stooping at an investigator who was climbing to a ferruginous hawk nest, and members of both pairs making multiple stoops at a golden eagle within the nesting area, but never at each other. Thurow and White (1983) argued that the mutualistic defense behavior of the shared general nesting area was beneficial for both species by increasing their defense capability against predators. Swainson's hawks chose to nest closer to active ferruginous hawk nests thereby reducing the size of the general nesting area of the two pairs and making defense of the shared nesting area more effective.

Because ferruginous hawks are highly sensitive to human disturbance during the reproductive period (White and Thurow 1985), monitoring and land management activities should not be conducted within sight of active nests during this time. Olendorff (1993) recommended safe dates for entry into nesting areas as a minimum of 99 days from egg-laying, or 68 days from hatching.

Factors affecting productivity

Ferruginous hawk productivity is closely tied to the density of major prey items (Stalmaster 1988, Schmutz and Hungle 1989, Woffinden and Murphy 1989, Cook et al. 2003). Several researchers have reported strong correlations between jackrabbit abundance and ferruginous hawk productivity (Smith and Murphy 1979, Thurow et al. 1980, White and Thurow 1985, Woffinden and Murphy 1989), or ground squirrel/prairie dog abundance and ferruginous hawk productivity (Steehnof and Kochert 1985, Schmutz and Hungle 1989, Schmutz 1991, Cook et al. 2003). If primary prey populations decline and alternate prey is not readily available, ferruginous hawk productivity declines as well; in Utah, where alternate prey was not abundant during a jackrabbit decline, 89 percent of ferruginous hawk pairs nested in high jackrabbit years, as opposed to only 43 percent during low jackrabbit years (Smith and Murphy 1979). Furthermore, average clutch size and number of young per successful nest decreased during low jackrabbit years (Woffinden and Murphy 1977).

Demography

Genetics

There is no published information regarding genetic demographic analysis of spatially disjunct ferruginous hawk populations. Intuitively, the Continental Divide would be the most logical potential barrier to genetic exchange between ferruginous hawk populations, and breeding populations on either side would be expected to show the most genetic variation. There is evidence that morphometric characteristics of females differ on either side of the Divide (Gossett 1993), reflecting some degree of genetic differentiation. However, Watson (2003) found that the Continental Divide was not a barrier to hawk migration. This finding, coupled with reports of a potentially high incidence of nomadism of breeding pairs during low prey years (Smith and Murphy 1979, Woffinden and Murphy 1989), leads to speculation that genetic isolation is probably not a serious concern, even for small populations of ferruginous hawks.

Life history characteristics and life cycle analysis

Population Viability Analyses (PVA) requires precise estimates of vital rates such as fecundity, survival, immigration, and emigration. Because no reliable estimates of all necessary vital rates have been published, a PVA has not been developed for the ferruginous hawk. While numerous estimates of productivity have been reported, these estimates vary widely both spatially and temporally. In addition, reliable estimates of survival rates of different age classes are lacking. However, a few estimates of vital rates are available from disparate parts of the ferruginous hawk range. Using this information, we developed a 2-stage matrix model (**Figure 7**) and examined the properties of the model using sensitivity and elasticity analyses. Through sensitivity analysis we examined the sensitivity of λ (the finite rate of population change) to changes in different vital rate parameters. Through elasticity analysis, we examined the proportional sensitivity of λ to proportional changes in vital rates.

The advantage of a stage-classified model rather than an age-classified model lies in consolidating discrete age-classes that have similar vital rate parameter estimates into single stages. In the life cycle diagram (**Figure 7**), the first stage represents juvenile (less than 1 year) female ferruginous hawks, and the second stage is comprised of all ages (>1 year) of sub-adult and adult

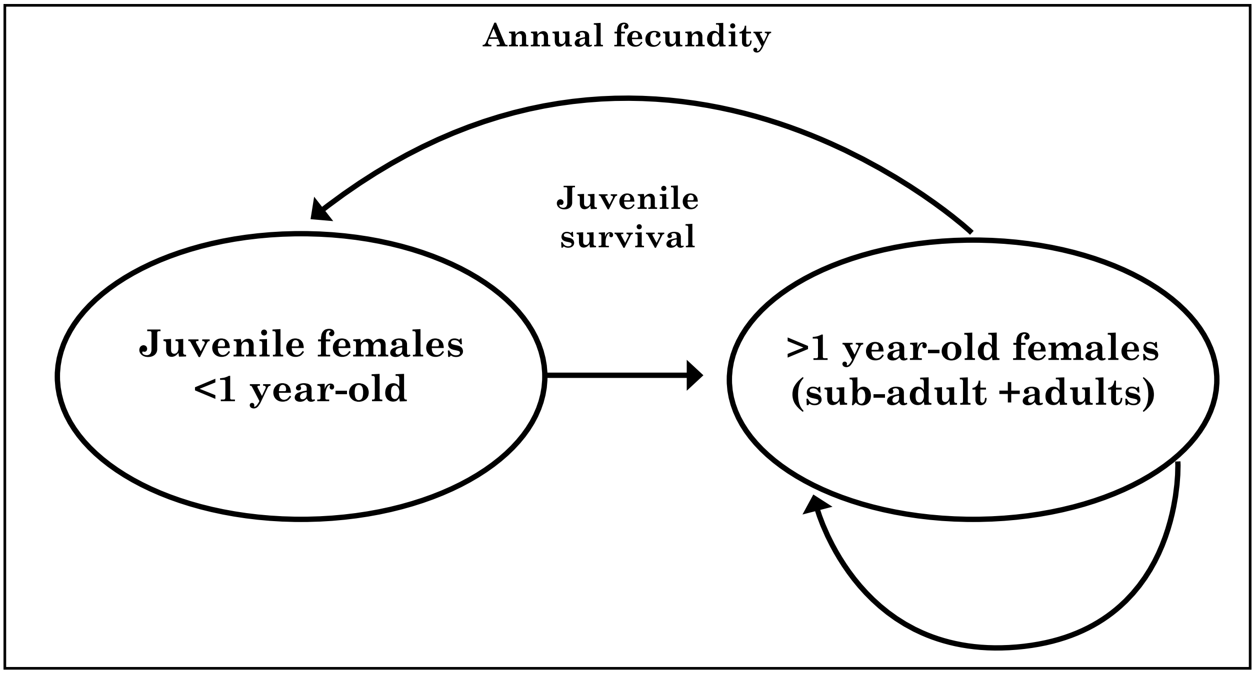


Figure 7. Life cycle diagram of a generalized ferruginous hawk population used in the development of a stage-classified matrix model for Region 2. Ferruginous hawks are most accurately represented by a 3-stage model including sub-adults; however, vital rate parameters were not available for sub-adults. Only females are modeled because they determine fecundity.

females, rather than several discrete age classes as in an age-classified model. The pathway from juveniles to adults represents juvenile survival (the probability of surviving from Stage 1 to Stage 2), the pathway from adults to juveniles represents the annual productivity of adults (specifically fecundity, the mean number of females recruited into the juvenile population per female per year), and the circular pathway on the adult node represents adult annual survival (the probability of remaining in Stage 2). Ferruginous hawks are most accurately represented by a 3-stage model including sub-adults. However, vital rate parameters are not available for sub-adults. We assumed that vital rate parameters of sub-adults are identical to those of adults, a reasonable assumption since sub-adults are reported to breed regularly (Bechard and Schmutz 1995).

In Utah, Woffinden and Murphy (1989) estimated adult annual survival as low as 0.75, but this is probably an underestimate due to nomadism, and unreliable because the estimate was not based on telemetered individuals. A more reliable estimate was provided by Watson (2003), in Washington, who estimated annual survival rates using satellite Platform Transmitter Terminals (PTTs). Cumulative survival of adults was 0.46 (n = 13) during four years of the study, indicating a mean annual adult survival rate of 0.87 (**Figure 8**). Schmutz and Fyfe (1987) estimated annual juvenile survival of 0.34 for ferruginous hawks banded in Alberta. This is probably an underestimate because most mortalities were human-related (Bechard and Schmutz 1995). Watson (2003), again using PTTs, estimated an annual juvenile survival rate of 0.43 (n = 15) in Washington. We assumed annual survival rates of 0.87 and 0.43 for adult and juvenile ferruginous hawks, respectively, for use in the matrix model because these estimates were based on telemetered individuals. We assumed annual survival did not vary with gender. We assumed the survival estimates were accurate and representative, but recognized the small sample sizes of telemetered individuals as a drawback.

Mean annual productivity (mean number of fledglings per breeding pair per year) estimates vary widely, ranging from lows of 0.5 to 0.6 in Utah (Weston 1968, Woffinden and Murphy 1989) and Wyoming (Platt 1986) to 4.0 in Saskatchewan (Houston 1991). Within Region 2, mean annual productivity ranged from lows of 0.5 to 0.8 in Colorado and Wyoming (Platt 1986, Stalmaster 1988) to a high of 3.5 in Colorado (Call and Tigner 1991). In 13 studies reporting 49 annual productivity estimates, the mean number of fledglings per breeding pair in Region 2 was 1.9. We chose this as the mean productivity for entry into the matrix model.

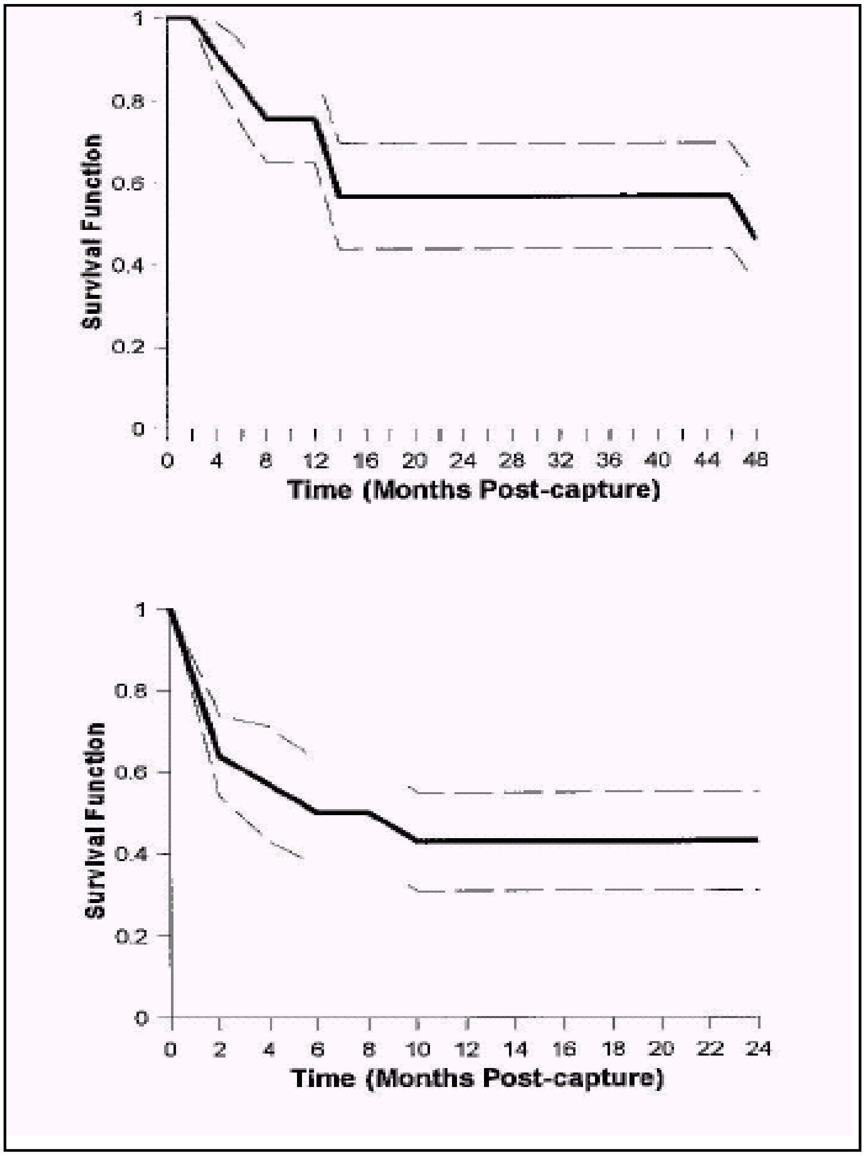


Figure 8. Kaplan-Meier (1958) survival estimates of telemetered adult (top) and juvenile (bottom) ferruginous hawks in Washington, 1999-2003. Hawks were captured in June. From Watson (2003).

Little information is available regarding the proportion of ferruginous hawk pairs that nest annually. However, nesting effort is correlated with prey availability (Schmutz and Hungle 1989, Woffinden and Murphy 1989). In Utah, 89 percent of pairs nested during high prey years, compared to 43 percent during low prey years (Smith and Murphy 1979). It is conceivable that 100 percent of pairs could nest in years of superabundant prey, especially if secondary prey is available. Therefore, we conducted separate sensitivity/elasticity analyses for each of the following proportions of pairs nesting: a maximum of 100 percent, the reported minimum of 43 percent, and the midpoint of 72 percent.

The demographic input values (**Table 5**), then, are as follows:

- survival for juveniles = 0.43
- survival for sub-adults and adults = 0.87
- fecundity for juveniles = 0
- fecundity for sub-adults and adults = 0.41, 0.29, and 0.18.

Fecundity estimates for the sub-adult/adult stage were derived using 1.9 as the mean productivity,

Table 5. Results of sensitivity (and elasticity in parentheses) analyses of a 2-stage, stochastic projection model developed for the ferruginous hawk in USFS Region 2. Input values represent the numerical parameter estimates used in the model. Output values represent the sensitivity of λ to absolute (sensitivity) or proportional (elasticity) changes in vital rate parameters. See text for details of vital rate estimates.

	Nesting Scenarios		
Input values	**1**	**2**	**3**
Juvenile fecundity	0.00	0.00	0.00
Juvenile survival	0.43	0.43	0.43
Adult fecundity	0.41	0.29	0.18
Adult survival	0.81	0.87	0.87
Resulting output values			
Juvenile fecundity	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Juvenile survival	0.61 (0.19)	0.68 (0.16)	0.76 (0.12)
Adult fecundity	0.25 (0.19)	0.20 (0.16)	0.14 (0.12)
Adult survival	0.81 (0.62)	0.84 (0.68)	0.88 (0.76)

reduced by 50 percent assuming a 50:50 sex ratio at fledging, multiplied by the three different proportions (1.00, 0.72, and 0.43) of females that attempted to nest, then multiplied by juvenile survival (0.43). The model assumes that adult and juvenile survival and fecundity are time-invariant within each stage.

The results of the sensitivity/elasticity analysis of these data indicate that the sensitivities of λ to absolute changes (sensitivity) in survival rates of both juveniles and adults were nearly equivalent while λ was much less sensitive to changes in adult fecundity (**Table 5**). As adult fecundity decreased, λ became more sensitive to changes in survival of both juveniles and adults. In addition, the sensitivity of λ to a proportional change (elasticity) in adult survival was much greater than for juvenile survival or adult fecundity. This is consistent with the findings of Saether and Bakke (2000), who reported that the greatest contribution of adult survival rate to the population growth rate of avian species occurred in long-lived species with early (less than 3 years) age at maturity, and relatively large clutch sizes. The ferruginous hawk exhibits such a life history strategy, and Seather and Bakke (2000) suggested that such a strategy represented a bet-hedging strategy, i.e., producing a large number of offspring in some occasional good years. The high sensitivity and elasticity of λ to adult survival rates suggest that monitoring adult survival is the most important factor in assessing ferruginous hawk population health and trends. Furthermore, while a proportional change in adult fecundity does not affect λ to the same degree as an equivalent change in adult survival, λ is still quite sensitive to variation in fecundity. This raises the point that although a factor may have high elasticity or sensitivity, the mathematics of the matrix model does not address the political, financial, or logistical constraints that may be imposed on our ability to manage that specific factor (Nichols et al. 1980, Silvertown et al. 1996, Citta and Mills 1999, Reed et al. 2002). In certain instances, management actions focused on factors other than the one with the highest elasticity or sensitivity may produce the largest influence on population change (Nichols and Hines 2002). In the case of the ferruginous hawk, even though adult survival may be the demographic factor most likely to affect population trends, it should be noted that management efforts focused on affecting fecundity may be the most viable, influential, and economical.

The results of this simple analysis indicate that monitoring and management efforts would best be directed toward adult survival and fecundity. However, the structure of the matrix model included assumptions that have not been validated (e.g., a 3-stage model including sub-adults may be most appropriate), and the model was based on data from disparate parts of the ferruginous hawks' range, as well as small sample sizes. More accurate estimates or validation of the vital rates used in the matrix model are needed, as well as temporal variances and covariances among matrix elements (Saether and Bakke 2000).

Ecological influences on survival and reproduction

The life history strategy of ferruginous hawks is characterized by a long lifespan and the ability to produce many offspring when conditions are favorable. During periods that are unfavorable for reproduction, e.g., a crash in the primary prey population, long lifespan ensures that a significant portion of the breeding population will survive to take advantage of improved conditions. Prey availability is the primary factor affecting annual variation in survival and reproduction of ferruginous hawks (Smith and Murphy 1979). In turn, the cyclic availability of prey is often a complex stochastic process, influenced by numerous biotic factors (e.g., density-dependent and independent influences on vital rates; disease and parasites) and abiotic factors (e.g., climatic conditions). Likewise, ecological influences affecting ferruginous hawk survival and reproduction can be complex. For example, Woffinden and Murphy (1989) speculated that invasion of cheatgrass (*Bromus tectorum*) in central Utah led to the disappearance of halogeton (*Halogeton glomeratus*), which was one of two plant species (the other being greasewood [*Sarcobatus vermiculatus*]) required by jackrabbits during July and August because of its high water content. Cheatgrass replacement of halogeton stands, a result of abnormally high precipitation the previous winter, along with partial destruction of the greasewood community, led to a decline in the jackrabbit population and a concomitant decline in breeding ferruginous hawk abundance and productivity.

Stalmaster (1988) reported a negative correlation between ambient temperature and the number of active and successful nests, as well as the number of young at occupied nests. During seasons of below average temperatures, more nesting attempts were made, more were successful, and more young were produced. Roth and Marzluff (1989) reported the destruction of eggs and nests by hailstones and windstorms. Thus, weather can influence ferruginous hawk demographic parameters such as fecundity directly, as well as indirectly through its affects on prey abundance.

Factors limiting population growth

In general, four main factors limit the breeding success and potential population growth of ferruginous hawk populations:

- availability and security of nest substrate
- disturbances to nesting pairs
- sufficient prey base
- suitable habitat surrounding nest sites.

Given the results of the previously described matrix model, adult survival is potentially a fifth main factor that could limit the population growth of ferruginous hawks. Gossett (1993) summarized cause-specific mortality for 537 recoveries of banded ferruginous hawks between 1916 and 1992, and attributed 16 percent to shooting, 6 percent to vehicular collisions, 5 percent due to other injuries, and 3 percent to collisions with high tension wires or towers. Causes for the remainder of the mortalities were not identified.

Spatial structure

Spatial structure refers to the pattern by which birds distribute themselves over the landscape in relation to resources, conspecifics or congeners, and predators. Two important measures of spatial structure are dispersion (the regular spacing of individuals or pairs across the landscape) and density. For ferruginous hawks, understanding the factors that affect dispersion and density are important for assessing the quality of existing or potential habitat.

Most studies have focused on the spatial structure of ferruginous hawk populations during the breeding season. As in many raptor species, territoriality is the mechanism that determines the spatial structure of breeding ferruginous hawks (Schmutz et al. 1980). Nesting pairs defend a territory against conspecifics or congeners through aggressive interactions and displays (Smith and Murphy 1973, Schmutz 1989a). Provided that size of territory varies depending on habitat quality (i.e., prey abundance), population density is controlled by territoriality (Krebs 1994). In 11 studies, the mean “nearest neighbor” distance between ferruginous hawk nests was 3.4 km (range 0.8 - 7.2 km; Olendorff 1993). Although not specifically addressed by any studies, the variation in nearest neighbor distance is likely a function of habitat quality, provided suitable nest sites are not limiting.

In Region 2, mean nearest neighbor distance was 2.6 to 7.2 km in South Dakota (Lokemoen and Duebbert 1976, Blair 1978) and 4.0 km in Wyoming (Lockhart et al. 1980), while densities ranged from 16.9 km^2 per pair in Wyoming (Platt 1986) to 879 km^2 per pair in Kansas (Roth and Marzluff 1989). In different study areas within Region 2, certain areas consistently had larger or smaller densities of breeding ferruginous hawks. For example, in nine years of study in Kansas, mean breeding density was 773 km^2 per pair (range 537 - 879 km^2 per pair; Roth and Marzluff 1989), while mean breeding density in seven years of study in Wyoming was 30 km^2 per pair (range 17 - 51 km^2 per pair; Platt 1986). Habitat quality is likely the primary factor influencing the variability in breeding densities of ferruginous hawks. Assuming habitat quality influences territoriality and therefore density of breeding pairs in Region 2, it also influences the number of non-breeding individuals. If a given amount of habitat can only support a number of territories that is less than the number of potentially breeding individuals, there will be a surplus of potential breeders (Schmutz 1989a). Habitat quality, and therefore territory size, may vary annually. Thus, spatial structure of breeding populations influences the demographic parameters such as the proportion of potential breeders that actually breed in a given year.

The spatial structure of non-breeding and wintering ferruginous hawks, and the effects on ferruginous hawk demographics, is largely unknown. However, territoriality is not evident during winter. Multiple individuals often congregate at food sources, such as prairie dog towns, where they do not display aggressive interspecific behavior resembling that seen during the breeding season, often feeding and roosting less than 1 m from each other (Bechard and Schmutz 1995). It is unknown whether pairs of ferruginous hawks that remain on or near their breeding territories in the southern extent of the species' breeding range exhibit any significant territorial behavior during times outside of the reproductive period.

Metapopulation structure

There is no published information regarding ferruginous hawk population demographics in a metapopulation context. However, because ferruginous hawk habitat is not continuously distributed across the landscape, there is the potential for the existence of a metapopulation structure. Regional and temporal variation in prey abundance has been shown to result in local ferruginous hawk population declines or extinctions (Woffinden and Murphy 1989). Due to reports of nomadism, it is likely that extirpated local populations may be recolonized by nomadic individuals when prey populations recover, but this is speculative. The spatial extent at which a metapopulation structure might operate is also speculative but is likely to be sizeable due to the potential for long distance movements of ferruginous hawks (Watson 2003).

Community ecology

Predation

The role of predators in controlling prey populations has been the focus of debate in the ecological literature for some time (Edminster 1939, Huffaker 1958, Errington 1963, Paine 1974, Hansson and Henttonen 1988, Hanski et al. 1991, Batzli 1992, 1996, Stenseth and Ims 1993, Norrdahl 1995, Norrdahl and Korpimäki 1995, Korpimäki and Krebs 1996, Krebs 1996, Stenseth et al. 1996). Other studies (Keith 1990, Krebs et al. 1995, Selas et al. 2002) have suggested that other factors such as food availability/quality determine prey abundance, which may in turn drive predator numbers.

As noted earlier, ferruginous hawks are relatively specialized predators that rely almost exclusively on a single prey species in some areas. Bent (1937: 285) implied that ferruginous hawks could limit the abundance of their prey, stating that early during the last century shooting reduced the ferruginous hawk "to the verge of extinction and allowed ground squirrels to increase". Theoretical and field studies imply that resident specialist predators are able to cause limited cycles in predator-prey systems (Korpimäki and Norrdahl 1989, 1991, Korpimäki 1993, Hanski et al. 1991, 1993, Korpimäki and Krebs 1996). No research has been conducted specifically regarding the role of ferruginous hawks in limiting their prey populations. However, breeding avian predators must hunt in the vicinity of their nests from onset of egg-laying until post-fledging, and may contribute to crashes of summer populations of voles in Europe (Korpimäki and Norrdahl 1998). In northern Finland, where goshawks (*Accipiter gentilis*) specialize to some degree on grouse (*Tetrao tetrix*, *T. urogallus*, *Bonasa bonasia*, *Lagopus logopus*), up to 40 percent of grouse populations were removed by goshawks during the breeding season (Tornberg 2001), indicating that an avian predator can significantly affect the abundance of its primary prey populations. Similarly, it is possible that breeding ferruginous hawks could significantly reduce prey populations within their breeding home range. In addition, when not breeding, ferruginous hawks are able to seek out areas of high prey abundance or availability (Watson 2003) and may depress local prey populations during winter when gathered at concentrated food sources such as prairie dog towns.

Although ferruginous hawks are predators, they are occasionally preyed upon by other species. This is especially evident during the egg-laying and incubation period, when eggs are subject to depredation by numerous avian predators and, if the nest is accessible, mammalian predators. During the nestling period, nestlings may be killed by great horned owls (*Bubo virginianus*), golden eagles, American crows (*Corvus brachyrynchos*), and common ravens (*C. corax*) (Palmer 1988). In addition, fledglings are subject to predation by numerous mammalian predators after leaving the nest, and incubating females on ground nests are also vulnerable to mammalian predators (Bechard and Schmutz 1995).

Competition

Ferruginous hawks, Swainson's hawks, and red-tailed hawks often occur sympatrically (Restani 1991, Olendorff 1993). Diet overlap among these three species is high (Olendorff 1993), ranging from 65 to 98 percent (Schmutz et al. 1980, Cottrell 1981, Thurow and White 1983, Steenhof and Kochert 1985, MacLaren 1986, Restani 1991), indicating potential competition for food. Furthermore, Thurow et al. (1980) observed that although ferruginous, Swainson's, and red-tailed hawks are broadly sympatric during the breeding season, one species is usually uncommon (but see Restani 1991). For example, the red-tailed hawk is the least common of the three species in Alberta (Schmutz et al. 1980) and south-central Idaho (Thurow et al. 1980) whereas Swainson's is the least common in southeastern Idaho (Smith and Murphy 1973) and southeastern Washington (Knight and Smith 1982). These observations suggest resource competition that results in some degree of ecological segregation among these three *Buteo* species (Restani 1991).

Indeed, the competitive exclusion principle (Hardin 1960) states that "complete competitors cannot co-exist". Although anecdotal, Smith and Murphy (1973) suggested that the ferruginous hawk was the dominant breeding *Buteo* in Utah, and that it appeared to displace red-tailed and Swainson's hawks, limiting the respective populations of these species within their study area. Several researchers have reported ecological segregation of these three species. Examples included partitioning of nest sites by height (Knight and Smith 1982) or relative location on the larger landscape (Restani 1991), moderate divergence in similarity of diet (Thurow and White 1983, Restani 1991), temporal differences in daily peak hunting activity (Smith and Murphy 1973), offset breeding chronology (Smith and Murphy 1973, White and Thurow 1983), and spatial segregation of nests; nests of ferruginous and Swainson's hawk less than 0.3 km apart exhibited reduced productivity (Schmutz et al. 1980).

Disease and parasites

Little information is available regarding the role of disease in ferruginous hawk ecology. Individuals have been diagnosed with bacterial infections known as *bumblefoot*, caused by *Staphylococcus aureus* (Friend and Franson 1999), and protozoan blood parasites *Haemoproteus elani* and *Leucocytozoan toddi* (Bechard and Schmutz 1995). In addition, blowfly larvae (Calliphoridae) are common in the ears of nestlings, and mites may chew feathers on the throat (Bechard and Schmutz 1995). West Nile Virus, a recently emerged disease, has been documented in ferruginous hawks (U.S. Department of Health and Human Services, Centers for Disease Control 2005; see Exotic species section).

Symbiotic and mutualistic interactions

As described earlier, ferruginous hawks may have a mutualistic relationship with sympatric Swainson's hawks during the breeding season (Thurow and White 1983). By nesting closer together than would be expected if nest sites were chosen at random, productivity of both species may be increased (but see Schmutz et al. 1980). However, no statistically significant relationship has been documented, perhaps due to small sample sizes (Thurow and White 1983).

Passerines such as the western kingbird (*Tyrannus verticalis*) and house sparrow (*Passer domesticus*) may nest immediately below or within ferruginous hawk nests (Konrad and Gilmer 1982). It is thought that the passerines may benefit from this nesting strategy by obtaining food from insects attracted to carrion, excrement, or dead nestlings at ferruginous hawk nests (Konrad and Gilmer 1982). In addition, the presence of hawks may afford nesting passerines some measure of protection from potential passerine predators. Conversely, passerines nesting in the vicinity of ferruginous hawk nests may alert the hawks to the presence of nest predators.

Model of environmental linkages

To demonstrate the myriad of environmental linkages between the ferruginous hawk and its community, we constructed an envirogram (**Figure 9**) based on the concept of Andrewartha and Birch (1984). They define an envirogram as "a dendrogram whose branches trace pathways from distal causes in the web to proximate causes in the centrum." The centrum is comprised of resources that directly affect the abundance of the target organism and are traditionally divided into four categories: resources, mates (reproduction), survival, and predators. The web is comprised of indirect influences that can affect the abundance of the target organism by modifying any one of its centrum categories. Within each centrum category, the relationship between the target organism and each of the most distal influences in its environment is outlined in a linear fashion. The linear design of

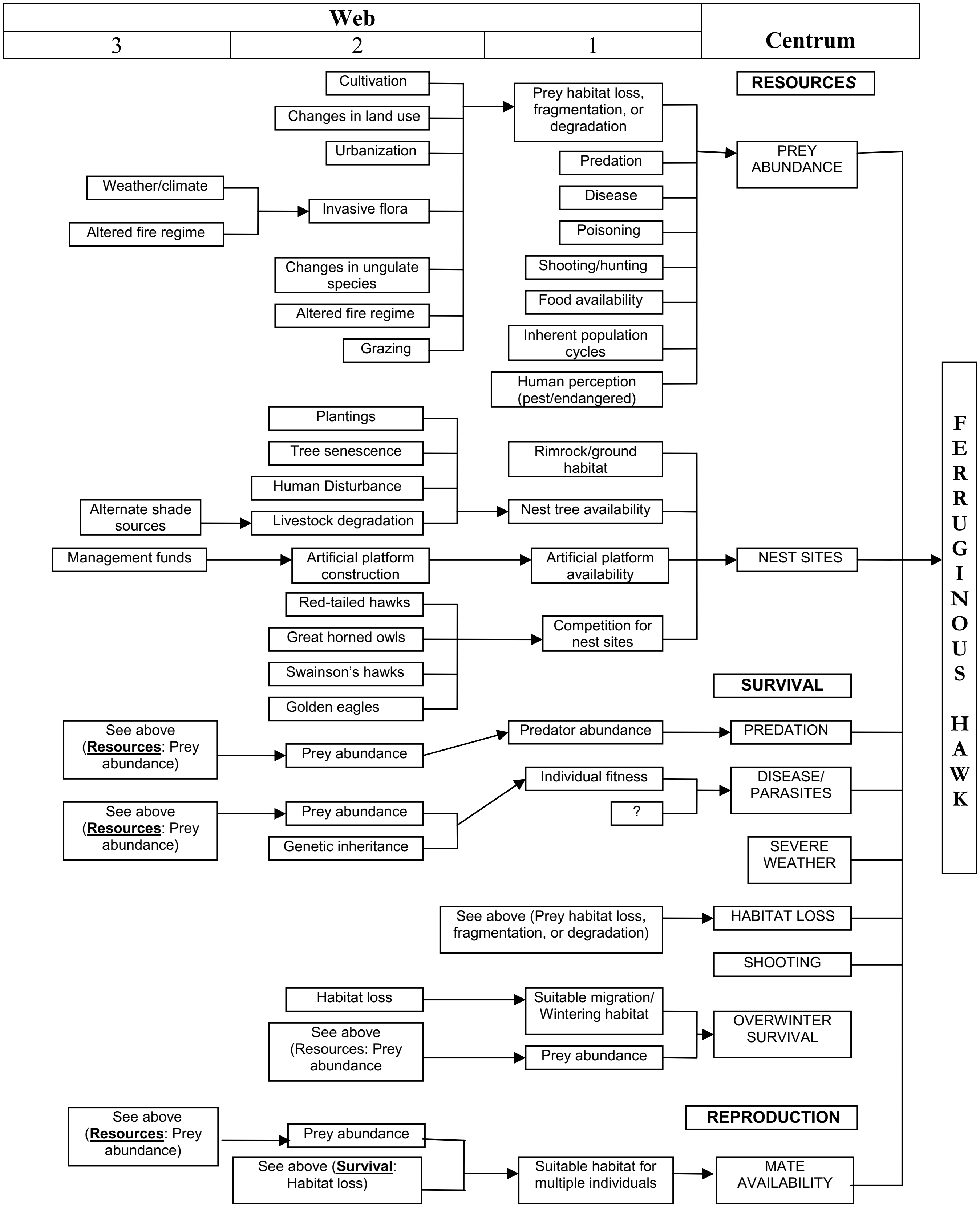


Figure 9. Envirogram illustrating ecological relationships of the ferruginous hawk and its environment.

the envirogram facilitates assessment of individual components and their relation to the ferruginous hawk's biology as a whole. Because the relationship between components is simplified to one-way interactions, the resulting diagrammatic representation simplifies visual assimilation of a great deal of information. The environmental linkages depicted in **Figure 9** are developed from this document, but they do not necessarily represent all possible relationships. It should be noted that while not explicitly depicted, factors such as natural selection, human globalization, and climate change are pervasive and may affect nearly every factor within each branch of the envirogram.

Conservation

Threats

Many threats to ferruginous hawk populations have been referred to or briefly discussed in this document. This section provides in-depth discussion of the primary threats to ferruginous hawk populations, based on the synthesis of literature contained in this conservation assessment. While all of these threats may be wholly or partially applicable to ferruginous hawk populations throughout its range, the following discussion is focused on threats that are particularly relevant to ferruginous hawk populations within Region 2. Foremost among threats facing Region 2 ferruginous hawks is habitat loss, fragmentation, or degradation resulting from land use practices including conversion of native habitat to agriculture, urbanization, improper grazing practices, and conversion of shrubland to grassland. Other threats include human disturbance during the reproductive period, reduction of prey populations through poisoning and disease, energy resource development, altered fire regimes, and invasion of exotic species, including new diseases.

Habitat loss

Land conversion to agriculture

Loss of habitat, particularly suitable breeding habitat, is the foremost threat to the security of ferruginous hawk populations throughout its current range. Conversion of native habitat to agriculture, as well as urbanization, results in a direct loss of all or a significant portion of ferruginous hawk habitat where such conversions occur. The amount of undisturbed natural habitat within the ferruginous hawk's Region 2 range has been significantly reduced or altered, which may make the population vulnerable through reduced survival and/or productivity.

The eastern portion of the ferruginous hawk's range includes some of the most productive cropland in North America. In Canada, more than 99 percent of the tallgrass prairie, 82 percent of the shortgrass prairie, and 75 percent of the mixed grass prairie has been converted to agriculture (Gauthier and Henry 1989). A similar trend has occurred in the United States; losses of native Great Plains grassland total 99.9 percent for tallgrass prairie in many states and 70 to 80 percent for mixed-grass prairie (U.S. Geological Survey 2001), the majority having been lost due to conversion to agriculture. Intensive agriculture converts native habitats into less useful habitat by altering the key components of ferruginous hawk breeding habitat: prey availability and nesting substrates.

While the bulk of native grasslands have already been lost, the trend continues on residual patches. With the advent of rock-picking machines, grasslands that were once considered unsuitable for cultivation are being converted to agriculture. The conversion to cropland is also facilitated by the advent of genetically altered crops, such as soybeans. These new strains are capable of growing on lands previously suitable only as rangeland. Furthermore, while the advent of the Conservation Reserve Program (CRP) may be viewed as valuable because it slows the trend of native habitat conversion to agriculture and actually returns previously cultivated land to grassland, the CRP program may inadvertently accelerate the loss of native habitats (Lesica 1995). Landowners often plow additional native prairie to replace the cropland they enrolled in CRP, or plow native prairie in anticipation of later retiring it to receive CRP payments. Thus, farmers are paid to take land out of production while at the same time additional native prairie is plowed and put into production. In addition, the species planted in CRP acreage, such as crested wheatgrass (*Agropyron cristatum*), often result in reduced biodiversity compared to native habitats (Knowles et al. 1996), and may not be suitable for primary ferruginous hawk prey species (e.g., black-tailed prairie dogs and ground squirrels) over the long-term (Lardy 1980, Olendorff 1993).

Through reduced prey numbers, reduction or elimination of nest substrates, and probably reduced survival, conversion of native habitat to intensive agriculture translates directly to a decline in ferruginous hawk breeding numbers, at local and potentially regional scales (Olendorff 1993). One exception was reported by Schmutz (1987a), who documented an increase in ferruginous hawk and ground squirrel abundance as cultivation occupied up to 30 percent of the land area. However, above 30 percent cultivation, ferruginous hawk density declined, as did the abundance of ground squirrels, the primary prey species on the study area. Several other researchers have reported a negative relationship between breeding ferruginous hawks and cultivation; only 1 percent of nests in Idaho and Utah had traces of cultivated land in the vicinity (Howard 1975, Howard and Wolfe 1976), and only 3 percent of nests in South Dakota were on cultivated land (Blair 1978). Similarly, only 2 percent of ferruginous hawk nests in Oregon were on cultivated lands, much less than expected based on availability (Cottrell 1981). Although cropland was abundant in Roth and Marzluff's (1989) study area in Kansas, ferruginous hawks rarely incorporated much of it into their nesting areas. The results of these studies stress the importance of prey abundance and availability to breeding ferruginous hawks. Cultivated lands are avoided by breeding hawks because of decreased prey abundances, decreased prey availability resulting from greater vegetation cover of cultivated crops compared to native habitats, and human disturbance during reproductive periods.

Urbanization

Similar to the threat of land conversion to agriculture, urban development can affect individual ferruginous hawks and populations through reduced survival, habitat alteration, loss, fragmentation, and human disturbance (Cringan and Horak 1989). Metropolitan areas consisting of housing developments and industrial complexes obviously preclude ferruginous hawk use. Furthermore, metropolitan areas are almost always surrounded by suburbs, which include disturbance or mortality factors such as cultivated areas, power grid systems, highways, and recreation areas and airports, which are shunned by ferruginous hawks. Most ferruginous hawk populations are excluded for many kilometers around large metropolitan areas such as Denver and Fort Collins, Colorado, and Salt Lake City, Utah. Near Boulder, Colorado, Berry et al. (1998) reported that wintering ferruginous hawks occurred primarily on study plots with less than 5 percent urban development, and were only observed once during the breeding season. The threat of urbanization within Region 2 is most acute in Colorado, along the interface between the Rocky Mountains and Great Plains. This is also the area of black-tailed prairie dog occupancy that is most threatened by urbanization. During the 1990s, 19 percent (8,000 acres [3,270 ha]) of the remaining (most of the historically occupied habitat had already been lost) occupied black-tailed prairie dog habitat was lost to urbanization in the Denver/Fort Collins/Boulder metropolitan area (U.S. Fish and Wildlife Service 2000). Given the correlation between ferruginous hawk and prairie dog abundance (Cook et al. 2003), this likely represents a significant loss of ferruginous hawk habitat within the area.

Habitat degradation

Improper grazing practices

In addition to outright habitat loss and fragmentation due to land conversion to agriculture and urbanization, other land use activities threaten ferruginous hawk populations through habitat degradation. Foremost among these are improper livestock grazing practices. While rangelands managed for grazing are certainly more beneficial to ferruginous hawks than cultivated or urban areas, grazing can nevertheless be detrimental to ferruginous hawks in three ways: (1) changes in nest site availability, (2) effects on prey abundance, and (3) effects on prey vulnerability (Kochert et al. 1988).

Before any discussion of current grazing practices, it should be recognized that historically, the occupied range of ferruginous hawks in Region 2 was grazed by native ungulates, primarily bison (*Bison bison*), as well as by prairie dogs. Herbivory by free-ranging bison was not ecologically equivalent to historical or present livestock grazing regimes. Temporal and spatial patterns of landscape disturbance differ significantly between livestock and bison (Wuerthner 1997a). Bison were nomadic, grazing the landscape with high intensity and low frequency; livestock can graze the landscape in a similar manner provided that they are actively rotated. However, livestock are often allowed to graze the landscape with a high intensity/high frequency pattern, resulting in different effects on the landscape and ferruginous hawk prey species that co-evolved within the bison grazing regime. Livestock, if not actively rotated, also tend to concentrate in riparian areas containing water, excellent food sources, and tree groves that provide shade, thereby impacting those areas much more significantly than did bison (U.S. General Accounting Office 1988, Wuerthner 1997a). Many livestock grazing regimes do not allow grasses time to recover, altering the competitive relationship between grasses and shrubs, in turn leading to the conversion of grassland to shrubland (Wagner 1978). Therefore, much of the ferruginous hawk habitat within Region 2 has changed significantly since the disappearance of bison and the widespread introduction of domestic livestock. Where such habitat shifts produce a negative shift in prey abundance, ferruginous hawks may be adversely affected.

The impact of current livestock grazing regimes on ferruginous hawk populations and individuals may also directly and negatively affect nesting substrates, such as traditional nest trees (Olendorff 1993). Indeed, livestock often congregate under the limited trees that are typical of ferruginous hawk breeding habitat within Region 2, trampling the trees' root systems, eating seedlings needed for replacement of senescent trees, and girdling nest trees by using them as scratching posts (Olendorff 1973). These activities can pose a serious threat to ferruginous hawk productivity by eliminating suitable nest trees, or by direct disturbance to breeding ferruginous hawk pairs.

In addition, overgrazing can pose a serious indirect threat to ferruginous hawk populations through its effects on ferruginous hawk prey populations (Stewart 1975, Kochert et al. 1988, Kochert 1989). However, there can be potential short-term benefits of overgrazing to ferruginous hawks. In the short-term, overgrazing may increase certain prey densities as well as their vulnerability to ferruginous hawks, thereby providing short-term benefits to ferruginous hawk individuals and populations (Kochert et al. 1988). In general, long-term overstocking of rangelands is detrimental to ferruginous hawk prey populations, and, thus, to ferruginous hawks (Olendorff 1993). Seemingly, there is a conflict for managers charged with providing optimal habitat for ferruginous hawk populations. However, as Olendorff (1993) pointed out, management for overgrazing in order to provide short-term benefits to ferruginous hawk populations is illogical in light of the possible catastrophic long-term effects on ecosystems. Grazing practices pose the least threat to ferruginous hawks when the vegetative structure in grazed areas is adequate to support high numbers of prey species, but not so dense as to significantly decrease prey vulnerability. The seriousness of the threat of improper grazing practices to ferruginous hawks across Region 2 is heterogeneous, and it is best evaluated by managers within each management area.

Land conversion from shrubland to grassland

This particular threat may not apply throughout much of Region 2 because most occupied ferruginous hawk territory is already grassland. However, some portions of Region 2, especially Wyoming, contain ferruginous hawk populations that occur primarily in shrub-steppe. Shrub conversion to grassland is typically undertaken to increase forage for livestock. Olendorff (1993) believed that conversion of shrubland to grassland was a significant threat to ferruginous hawk populations by causing a decrease in prey habitat richness and prey diversity. Unfortunately, the few studies that report effects of shrubland to grassland conversion on ferruginous hawk prey species, and, therefore, on ferruginous hawk populations, are equivocal, and in some cases, even conflicting (Olendorff 1993).

In southeastern Wyoming, a multi-agency study is underway that will address shrubland conversion through inventory and mapping of current shrub communities, comparison with past Landsat images, and compilation of records of past treatments (Marriot 2003). One goal of the project will be to identify areas where shrub management activities have become too numerous or frequent that they are potentially adversely affecting associated wildlife species. Projects such as these will better define the nature of the threat of shrubland conversion to grassland to ferruginous hawks in Wyoming and elsewhere throughout Region 2.

Given the relationship between prey and ferruginous hawk abundance, productivity, and distribution, conversion of shrubland to grassland (or grassland to shrubland) may be detrimental to ferruginous hawk populations if that conversion also brings with it a concomitant elimination or decrease in preferred ferruginous hawk prey species. However, Howard and Wolfe (1976) found that conversion of shrubland to crested wheatgrass did not adversely affect ferruginous hawk reproduction in Idaho and Utah. Instead, ferruginous hawks were able to exploit different prey in seeded grasslands compared to native desert shrub habitats in their study. Jackrabbits were more common and more heavily preyed upon by ferruginous hawks in shrub habitats, while pocket gophers and ground squirrels comprised the majority of prey populations in seeded grasslands and the majority of prey taken by ferruginous hawks. In contrast, in the late 1970s in Oregon, ground squirrel populations increased in abundance in crested wheatgrass conversions (Lardy 1980), but subsequently declined dramatically and had not recovered as of 1993 (Olendorff 1993). Therefore, conversion of shrubland to grassland may or may not be a significant threat to ferruginous hawk populations, but managers should carefully consider whether or not the risk of conversion is worth taking.

Human disturbance during the reproductive period

Activities that involve visits to active ferruginous hawk nests or that otherwise alter hawk behavior may cause individual nests to fail (Olendorff 1993). Most individuals are extremely sensitive during the early phases of nesting, and somewhat less so as the young near fledging. Individuals often became accustomed to routine disturbance especially if humans are not visibly associated with it (White and Thurow 1985). Brief disturbances that do not keep incubating females from eggs for a long duration are less detrimental as the female is more likely to return to incubation. However, more frequent disturbance or longer duration disturbances are likely to have substantial impacts, including nest desertion. Human activity near nests may also impact nestlings by causing them to fledge prematurely.

One widespread source of human disturbance is the increasing use of recreational vehicles, such as all-terrain vehicles, that can have negative consequences for ferruginous hawks. Habitat alteration due to the destruction or degradation of vegetation structure by recreational vehicles can adversely impact ferruginous hawk habitat. Perhaps just as significant are noise and other disturbances that affect individual ferruginous hawks physiologically (Busch 1977), and may reduce productivity at nest sites. The spate of likely activities allowed in areas designated for high-volume recreational vehicle use make successful nesting nearly impossible (Olendorff 1993). Federally administered lands are especially popular with recreational vehicle enthusiasts. Federal regulations regarding the proper use of recreational vehicles and closures are in place; however, if enforcement of these regulations is lacking, recreational vehicle disturbance may pose a significant threat to ferruginous hawks breeding on public land in Region 2. The extent of the threat of human disturbance to ferruginous hawks throughout Region 2 is unknown. However, human disturbance due to recreational activities such as hiking, mountain biking, recreational vehicle use, are likely to be more prominent with increasing proximity to urban centers (Berry et al. 1998), such as the Fort Collins/Denver/Boulder area.

Control (chemical and varmint shooting) of ferruginous hawk prey populations

Extensive chemical control of small mammal prey populations important to ferruginous hawks has been ongoing for many decades, supported by federal and state agencies, and private industry. Chemical control is used to reduce the density of small mammals, which are seen as forage competitors with livestock (Clark 1989) and as crop pests. Ferruginous hawks prey primarily on small mammals, and while secondary poisoning of raptors is known to occur, it is not thought to be a significant threat to ferruginous hawks (Newton 1979, Schmutz 1989b). The larger threat stems from reduction in major prey populations. Long-term rodent control programs ultimately reduce prey numbers, which can cause a measurable decrease in associated populations of ferruginous hawks (Olendorff 1993) through seasonal or temporary effects to prey species or local prey extinction over a number of years. Prairie dogs, a vital prey species for ferruginous hawks (Cook et al. 2003), were once estimated to number 5 billion individuals (Seton 1929) and occupy 40 million ha (U.S. Fish and Wildlife Service 2004). Presently, prairie dogs have been reduced by 98 to 99 percent over their range (Miller et al. 1994, U.S. Fish and Wildlife Service 2004). Large declines in occupied prairie dog habitat have occurred throughout every state within Region 2 (Henderson and Little 1973, Clark and Stromberg 1987, Clark 1989, Nebraska Game and Parks Commission 1993, South Dakota Game, Fish, and Parks Department 1996, Colorado Division of Wildlife 2002), due in large degree to chemical control.

The black-tailed prairie dog was found to be warranted, but precluded from listing as a federally threatened species in 2000 (U.S. Fish and Wildlife Service 2000), and most chemical control efforts on federal land ceased at that time. However, the species was removed from the candidate list in 2004 when USFWS concluded that federal listing was not warranted (U.S. Fish and Wildlife Service 2004), and chemical control of black-tailed prairie dogs on federal lands is again underway in South Dakota (Miller 2004). State agencies also are again involved in chemical control of prairie dogs throughout Region 2 (Rocky Mountain Animal Defense 2004). Given the precipitous decline of the black-tailed prairie dog over several decades, and its importance as ferruginous hawk prey, the continued decline and potential extirpation of black-tailed prairie dogs and other small mammals, due in part to chemical control (Wuerthner 1997b), pose a significant and persistent threat to ferruginous hawks within Region 2.

Harmata and Restani (1995) thought that the use of lead shot in upland game hunting and lead bullets in varmint and big game hunting was a significant source of lead poisoning in golden and some bald eagles. Varmint hunting involves recreational shooting of prairie dogs, ground squirrels, rabbits, and other small mammals. Typically, the carcasses are left in the field, and up to 30 golden eagles have been observed following varmint hunters from field to field, scavenging ground squirrels after the shooters had moved on (Harmata and Restani 1995). There is no reason that ferruginous hawks could not also scavenge wounded or recently killed small mammals, exposing themselves to lead, an additional threat to that imposed by a reduction in prey numbers due to varmint shooting.

Ferruginous hawk prey disease

Beginning around 1900, sylvatic plague (*Yersinia pestis*) was introduced from Asia to rodent populations on the Pacific coast of North America (Cully 1989). Since that time, the disease has spread eastward, affecting sciurid and cricetid rodents, lagomorphs, and carnivores (Barnes 1982, Cully 1993). Currently, plague is limited to the western two-thirds of the range of the black-tailed prairie dog (absent in most of South Dakota and portions of Kansas, Nebraska, North Dakota, Texas, and Oklahoma; U.S. Fish and Wildlife Service 2004). Within the past year, plague has appeared for the first time in South Dakota (Associated Press 2005). The emergence of sylvatic plague has greatly reduced remaining populations of prairie dogs. Prairie dogs have almost no natural resistance to plague, and nearly all of the individuals in a colony suffer mortality when plague is introduced. Given the lack of natural resistance to sylvatic plague, currently unaffected prairie dog populations will almost certainly suffer declines when plague is introduced. Within Region 2, plague outbreaks have already negatively affected prairie dog populations in Wyoming and Colorado. Populations in Kansas, Nebraska and unaffected portions of South Dakota are likely to decline when sylvatic plague eventually arrives, as no areas are safe from infection (U.S. Fish and Wildlife Service 2000). Despite severe reductions in individual affected prairie dog colonies, the USFWS concluded "plague no longer appears to be as significant a threat as previously thought" (U.S. Fish and Wildlife Service 2004). This conclusion was based on recent new evidence regarding the effects of plague on black-tailed prairie dogs, including:

❖ high exposure doses of plague may be necessary for disease contraction in some individuals

❖ limited immune response has been observed in some individuals

❖ isolated, low-density populations can persist in plague-infected areas

❖ some sites have recovered to pre-plague levels following a plague epizootic (U.S. Fish and Wildlife Service 2004).

Nevertheless, the persistence of sylvatic plague in currently affected areas and its spread to unaffected areas within Region 2 pose a significant and persistent threat to prairie dog populations, and thus, to ferruginous hawks within the Region.

Energy resource development

Mining and energy development activities can threaten ferruginous hawks through disturbance, habitat alteration or loss, and reduction or loss of prey populations (Evans 1980). Energy resource development, including exploration, extraction, processing, and transportation may directly impact ferruginous hawks through decreased survival and productivity (Harmata 1991); however, Stalmaster (1988) found no significant impacts in northwestern Colorado. Some of the indirect activities associated with mining and energy development can cause greater long-term impacts than actual resource development activities (Evans 1980). For example, resource development often requires the presence of people living relatively close to development sites, leading to the creation of new houses, support facilities, new or upgraded transportation routes, and subsequent recreation activities. These factors place more people in the vicinity of nesting hawks, resulting in higher nest desertion and lower productivity at ferruginous hawk nest sites, and the potential for higher incidences of vehicle collisions with and shooting of ferruginous hawks.

The relatively recent development of coal bed methane (CBM) reserves, particularly in Wyoming and Colorado, will potentially affect a large proportion of the range of the ferruginous hawk in these areas. Significant CBM resources have been identified and are being extracted in the Raton Basin in south-central Colorado and the Powder River Basin in eastern Wyoming/southeastern Montana (**Figure 10**; ALL Consulting 2004). The Powder River Basin is currently the fastest growing region for CBM development, with a total of 14,000 wells in production, most in Wyoming (ALL Consulting 2004), and a projected total of 60,000 wells (U.S. Department of the Interior Bureau of Land Management 2003). In the Powder River Basin alone, 5,311 miles of power poles, 17,000 miles of new pipeline, and 20,000 miles of roads are estimated to be required, and wells will be spaced at an average of 1 per 80 acres (U.S. Department of Interior Bureau of Land Management 2003). Additional significant CBM resources have been identified in the Denver Basin of central Colorado, the Piceance Basin in northwestern Colorado, the Hanna-Carbon Basin in south-central

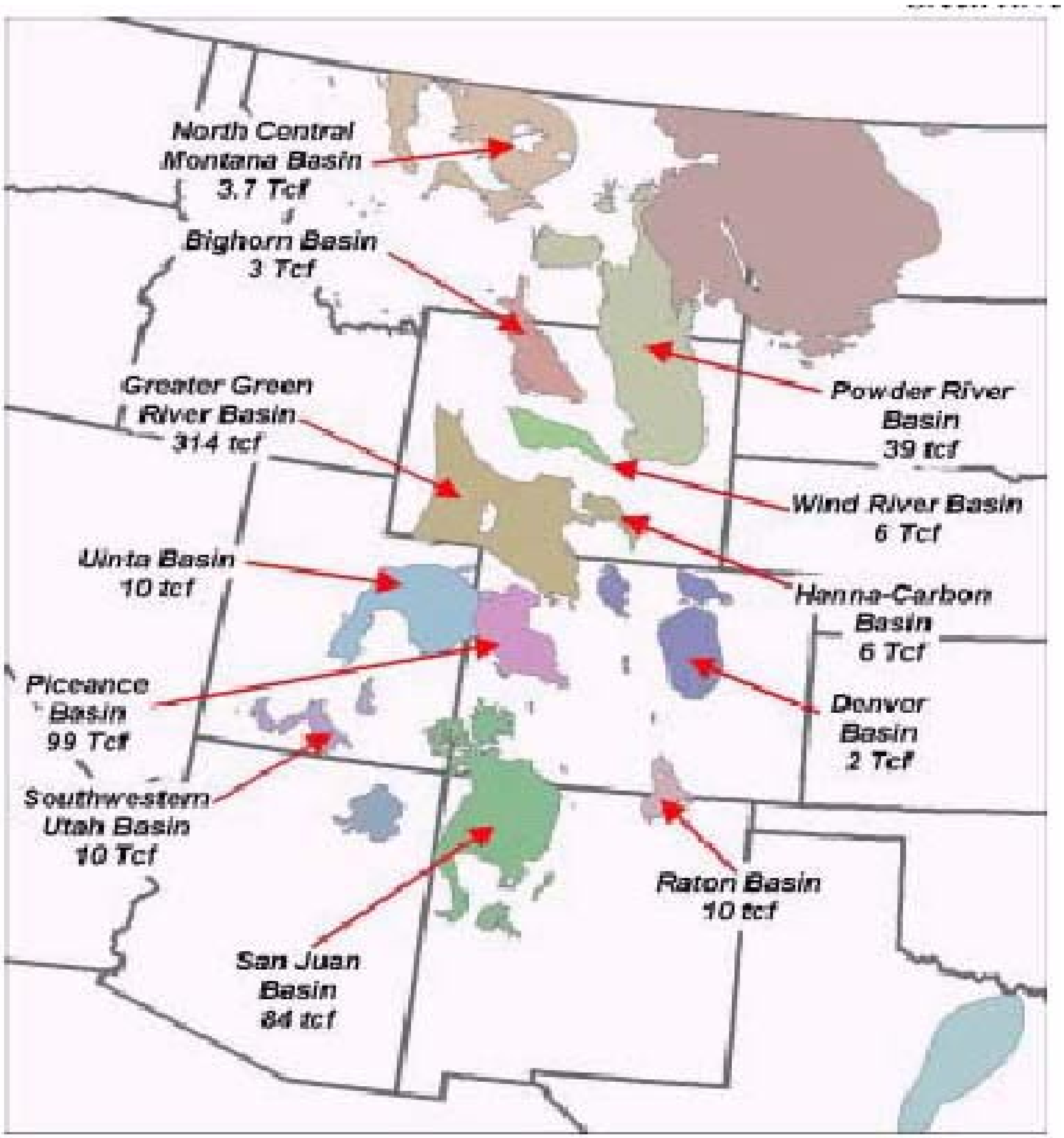


Figure 10. Rocky Mountain Region coal basins and estimated coal bed methane reserves in trillion cubic feet (tcf) (from Nelson 2000 in ALL Consulting 2004).

Wyoming, and the Greater Green River Basin in southwestern Wyoming (**Figure 10**; ALL Consulting 2004). It is anticipated that CBM production will begin or increase in all of these areas as demand for natural gas continues to increase.

Due to the expected large increase in the CBM industry and associated development in the Rocky Mountain Region, the potential exists for significant impacts to wildlife and habitats in Region 2, including ferruginous hawks. These threats include but are not limited to:

- increased habitat fragmentation
- increased human disturbance during the reproductive period
- potential changes in the abundance and diversity of primary prey species

- ❖ increased exotic vegetation establishment in newly disturbed areas
- ❖ increased risk of electrocution of ferruginous hawks due to additional power poles
- ❖ increased risk of collisions with vehicles and high tension wires.

The magnitude of the threat of energy resource development to ferruginous hawks in Region 2 is difficult to quantify. However, with the recent emergence and anticipated expansion of CBM development, as well as the persistence or increase in other energy resource extraction industries, the threat should be considered serious and will likely persist for many decades.

Altered fire regimes

Historically, fire return intervals were much shorter in the grasslands of the Great Plains prior to the 20th century (Brown and Sieg 1999). With the introduction of widespread fire suppression, the dynamic at the woodland/grassland ecotone was altered to favor encroachment of woody species, such as ponderosa pine (*Pinus ponderosa*), juniper, and shrubs, into grasslands. While scattered trees provide valuable nesting sites for ferruginous hawks, continuous fire suppression produces dense stands of trees in areas that were formerly grasslands, effectively removing these areas as ferruginous hawk habitat (Olendorff 1993).

In the Intermountain West, as much as 50 to 60 percent of native sagebrush-steppe now contains significant exotic annual grasses in the understory, or it has been completely converted to exotic annual grasslands (West 2000). Land-use activities such as livestock grazing have facilitated the spread of invasive plant species and altered fire and disturbance regimes (Rotenberry 1998). Once sagebrush ecosystems have been converted to annual grasslands, there is little, if any, chance of recovery to natural conditions (Knick et al. 2003). These altered ecosystems are occupied by a very different prey base, often rendering them less useful for ferruginous hawks.

Continued suppression of fires within grassland habitat is a threat to Region 2 ferruginous hawk populations. This threat can be lessened through the use of fire management tools such as prescribed burning and let-burn policies. The conversion of native shrub-steppe habitats to non-native annual grasslands through altered fire regimes is also a serious threat to ferruginous hawks in the Intermountain West, and areas of Region 2 such as Wyoming that contain large expanses of sagebrush.

Exotic species

Exotic animal species do not appear to be a significant threat to ferruginous hawk populations or individuals. However, exotic plant species that change the vegetative components and reduce habitat diversity may consequently alter prey populations and fire frequency and/or intensity, significantly impacting ferruginous hawks. The ability of native grasslands and shrublands to support viable small mammal populations may be compromised by the invasion of exotic annuals, especially cheatgrass and Russian thistle (*Salsola iberica*). Some exotic species, such as crested wheatgrass are planted extensively, particularly when reseeding burned or mined areas or when shrublands are converted to grasslands. Crested wheatgrass plantings result in a near monoculture, and change the vegetation physiognomy and degrade the soil characteristics, severely reducing the diversity and density of small mammal populations (Reynolds and Trost 1980). Small mammals are primarily vegetarians, feeding on a variety of seeds and other herbaceous material. Therefore, the dramatically reduced vegetation diversity available to small mammals in crested wheatgrass monocultures or other degraded landscapes dominated by exotics reduces the diversity and abundance of small mammals.

Much of the Great Plains region, which includes most of Region 2, has been altered by invasion of exotic species such as crested wheatgrass (Christian and Wilson 1999). In addition, much of the native sagebrush-steppe has been altered by invasive plant species or is under threat of significant alteration. Therefore, the current threat is significant and is likely to persist or worsen.

In 1999, West Nile Virus (WNV, *Flavivirus* spp.), an exotic disease, emerged in birds in New York and has quickly spread across the country. Many (284 to date) avian species are susceptible to the disease, including raptors (U.S. Department of Health and Human Services Centers for Disease Control 2005). Among raptors, red-tailed hawks, Cooper's hawks (*Accipiter cooperi*), northern goshawks, and great horned owls have been particularly hard-hit by WNV, and often suffer significant mortality rates upon infection (P. Redig personal communication 2005). Ferruginous hawks are not particularly susceptible to WNV mortality, and the disease does not pose a serious threat to the ferruginous hawk throughout its range (P. Redig personal communication 2005). Isolated cases of WNV rather than widespread outbreaks are the rule in ferruginous hawks. The threat of other newly emerging diseases such as avian influenza is thought to be minimal, but the threat of diseases that have yet to emerge is difficult to assess. After all, no one had heard of WNV in 1998, yet, a few years later it has significantly impacted some avian species.

Conservation Status of the Ferruginous Hawk in Region 2

All predator populations are only as viable as the prey populations upon which they rely. This is especially relevant for the ferruginous hawk, which relies upon relatively few prey species compared to other *Buteos*, and whose distribution and abundance are highly correlated with those of its prey (Bechard and Schmutz 1995). Historically, small mammal populations, especially black-tailed prairie dogs, were vastly more abundant and widely distributed throughout Region 2. Therefore, it is likely that the ferruginous hawk was also historically more abundant and widely distributed. While the magnitude of the probable ferruginous hawk decline from its historic to current distribution is uncertain, it is almost universally agreed that there has been a significant decline (Olendorff 1993, Hoffman and Smith 2003). This is reflected in its status as a sensitive species by the BLM and Region 2 of the USFS, a vulnerable species in Canada, multiple state statuses reflecting vulnerability, and various NGO official organization designations reflecting its ecological and biological sensitivity or vulnerability.

Most threats to ferruginous hawks in Region 2 are ultimately of anthropogenic origin. The long (over a century and a half) temporal scale at which many of these threats have acted in concert to cause the decline of the ferruginous hawk dates to the time when significant numbers of settlers began arriving in the West. Significant anthropogenic alteration of the Region 2 environment in which the ferruginous hawk evolved began at that time, with the extirpation of bison from nearly all of its range, the introduction of large-scale agriculture (resulting in conversion of native ferruginous hawk habitat), the introduction of widespread domestic livestock grazing, deliberate control of rodent populations, and shooting of ferruginous hawks. Managers should bear in mind the long time scale over which these threats emerged and evolved, and they should recognize that although particular populations of ferruginous hawks within Region 2 may currently appear to be stable, all of the threats that led to a decline over the past 150+ years are still present. Therefore, it is certainly possible that long-term declines of ferruginous hawk populations will continue.

The immunity of federally managed lands within Region 2 to certain threats, such as cultivation and urbanization, makes them especially valuable to the continued persistence of ferruginous hawks. Based on data provided by Gillihan et al. (2004a) and Olendorff (1993), USFS grasslands in Region 2 contain between 3 to 6 percent of the total breeding population of ferruginous hawks within the Region. This underscores the importance of non-National Forest System (non-NFS) lands to the conservation of ferruginous hawks within the Region. In contrast to NFS lands, most non-NFS lands are susceptible to all of the threats to ferruginous hawks described in the previous section. Because up to 97 percent of the breeding population of Region 2 ferruginous hawks may occur on non-NFS lands, inclusion of these lands in ferruginous hawk conservation and management strategies is imperative; any long-term conservation strategy based solely on NFS lands within Region 2 is unlikely to succeed.

Different areas of Region 2 vary in their current and potential ability to support viable populations of ferruginous hawks. Areas where prairie dogs are the primary prey source are highly susceptible to plague outbreaks, whereas areas with multiple prey species (e.g., lagomorphs and/or multiple sciurids) are more likely to sustain suitable prey populations from year to year. In addition, the distribution of suitable breeding habitat varies within Region 2. For example, most of eastern Wyoming contains suitable ferruginous hawk breeding habitat, whereas only limited portions of Kansas are currently suitable for breeding ferruginous hawks (**Appendix**).

Management of the Ferruginous Hawk in Region 2

Implications and potential conservation elements

Ferruginous hawks have high sensitivity to human disturbance during the reproductive period, and they depend largely on populations of small mammals whose abundance is inherently stochastic. Despite this, ferruginous hawks may respond positively to management activities. Available data suggest it may be possible to mitigate and adjust human activities to minimize anthropogenic impacts that are detrimental to ferruginous hawks.

Prey availability, human disturbance, nest site availability, and suitable habitat surrounding nest sites are the primary limiting factors for breeding ferruginous hawk populations (Gillihan et al. 2004a). Because the breeding season is an important period in their annual life cycle, these limiting factors are essential elements that should and can be addressed through management and conservation activities. On a local scale, when one or more of these limiting factors is apparent, there are often numerous management tools available to mitigate or lessen the threat. However, it should be recognized that the vulnerability of ferruginous hawks to human activities is a broad-scale issue, and retaining large tracts of intact grasslands in the midst of range-wide, ongoing urban sprawl presents the greatest challenge to the conservation of viable ferruginous hawk populations (Berry et al. 1998). Management plans that address these limiting factors using a coarse filter approach (i.e., focus on communities and ecosystems rather than individual nest sites or populations) are most likely to succeed. Although important, management activities that focus solely on protecting individual nest sites or small, isolated populations are not likely to conserve ferruginous hawk populations over the long term.

A network of grasslands and shrub-steppe communities that stretches across the species' breeding and wintering ranges, and migration routes, is desirable and achievable. These vegetation communities should contain a diverse mix of native species that support the persistence of an equally diverse prey population, for ferruginous hawks are only as abundant and widespread as their prey species. When these characteristics are included in management plans, ferruginous hawk numbers can be maintained or potentially increased.

Ferruginous hawks occur on public land managed by several agencies, as well as on extensive private lands within Region 2. Perhaps because of this heterogeneous distribution, no comprehensive management direction for ferruginous hawks currently exists in Region 2. Such a management strategy, coordinated by a Region 2 ferruginous hawk task force, is necessary to direct ecosystem management on a Region-wide scale that will address at least the primary threats to ferruginous hawks. This document can serve as a key tool in establishing ferruginous hawk research and management priorities within Region 2. An important priority is the development and implementation of a range-wide inventory and monitoring program (see Tools and practices section), which would provide valuable information regarding long-term population trends, and help to answer questions regarding the broad-scale distribution and abundance of the species. While such a resource-intensive program may not be realistically justifiable in light of a host of other threatened, endangered, or sensitive species in today's wildlife management arena (Restani and Marzluff 2001, 2002), one goal of this document is to prioritize and describe important management actions that will contribute to the Region-wide persistence or increase of ferruginous hawks. Therefore, a description of an Inventory and Monitoring Program is provided.

Tools and practices

Many specific management tools or strategies have been published whose aim is to conserve or increase ferruginous hawk populations (Howard and Wolfe 1976, Howard and Hilliard 1980, Jasikoff 1982, Olendorff 1993, Tigner et al. 1996, Gillihan et al. 2004a, 2004b). These range in scale from tools that target individual hawks to ecosystem-based management strategies. Many have been implemented, with varying degrees of success. The primary consideration when evaluating the viability of any management strategy is to compare the performance of the ferruginous hawk population within the area where the tool is implemented to other similar areas where the tool was not implemented (Olendorff 1993), preferably over time-spans that encompass the range of environmental variation experienced in the region.

Inventory and monitoring

Currently, no standardized range-wide or Region-wide inventory and monitoring program exists to specifically estimate and track trends in ferruginous hawk abundance. As discussed in the Population trends section, the BBS, CBC and Hawkwatch International attempt to monitor breeding, migration, and wintering trends in many species' abundance, including ferruginous hawks. However, because of nomadism, and the sparse distribution and broad-fronted migration inherent to ferruginous hawks, these surveys lack appropriate methodology to accurately detect significant population trends, let alone provide population estimates. As Olendorff (1993) pointed out, a well-designed and consistent inventory and monitoring effort is necessary if a true picture of ferruginous hawk numbers is to be gained.

Fortunately, a promising inventory and monitoring technique based on Sightability Modeling (Steinhorst and Samuel 1989, Unsworth et al. 1994) was developed in Wyoming, specifically for estimating numbers of breeding ferruginous hawks (Ayers and Anderson 1999). This technique combines traditional aerial survey methodology (line transect surveys) with predictive sightability models. Sightability models use logistic regression models based on variables associated with nests seen during aerial surveys to estimate and correct for the number of nests missed during surveys, thereby providing more accurate population estimates. During development of this particular model, eighteen observers, all unfamiliar with nest locations in a known population, searched for nests (located via prior ground searches, so all nests in study area were known) within 300 m of flight transects via a fixed-wing aircraft. Nest variables included status (active or inactive), incubation initiation date, fledging or failure date, condition (excellent, good, fair, poor, bad), association (presence of alternate nests within 200 m), substrate type, topography, and tree density (Ayers and Anderson 1999). Flight variables tested for their influence on nest-detection rates included aircraft speed, height, direction of travel, time of day, light condition, distance to nest, and observer experience level. During two validation surveys, 23.7 percent (14/59) and 36.5 percent (23/63) of the actual number of nests were detected. Sightability model predictions, with 90 percent confidence intervals, correctly estimated the true population in both validation surveys. Ayers and Anderson (1999) concluded that standardized aerial surveys, when used in conjunction with predictive sightability modeling, could provide unbiased population estimates of the abundance of nesting ferruginous hawks.

Precision of the sightability model is based on three sources of variance: model error, visibility correction error, and sampling error (Steinhorst and Samuel 1989). Precision is increased when (1) a large proportion of the total number of nests is detected (reduces visibility correction error), (2) sample size is large during the development phase (reduces model error), and (3) a large proportion of the population is surveyed (reduces sampling error). There is great potential for developing a highly precise sightability model for breeding ferruginous hawks in Region 2. Because many national grasslands within Region 2 contain large numbers of known ferruginous hawk nests (e.g., Thunder Basin National Grassland contains more than 200 known nest sites [Gillihan et al. 2004a]), model error during the development phase would be low. In addition, an entire "population" could be sampled (e.g., Thunder Basin National Grassland), thereby eliminating sampling error. As in the model developed by Ayers and Anderson (1999), visibility correction error would be the largest contributor to the variance of a sightability estimator for Region 2, and is reduced most by using experienced observers. The primary drawback of sightability modeling is the initial cost of model development and validation. However, once a model is sufficiently described and validated, costs are minimal relative to the accurate estimates obtained. Another disadvantage of this and the following approach are that they can only be conducted during the window encompassing the reproductive period.

While the application of sightability modeling would provide accurate estimates of ferruginous hawk breeding abundance and trends, it is also important for managers to understand what may be causing identified trends. Demographic monitoring is a valuable tool to accomplish this goal. Demographic monitoring attempts to track changes in the demographic parameters of a population, rather than abundance, and may help to elucidate the potential causes of any trends in abundance discovered through sightability modeling. The two most important and commonly estimated demographic parameters are survival and productivity (fecundity), which can be used to calculate the finite rate of increase (λ). These were also the two most important parameters identified in the sensitivity/elasticity model described previously. Both survival and productivity must be estimated to have any utility in models used to track population trends because population trends are due to the combined effects of survival, productivity, and in some cases, dispersal (Braun et al. 1996). Survival or productivity alone may not be correlated with abundance (Kennedy 1997). Several methods can be used to estimate demographic parameters. However, survival of ferruginous hawks is most accurately estimated using telemetered individuals (preferably satellite telemetry), while productivity is most accurately estimated by counting the number of chicks produced by breeding pairs. The primary advantage of demographic monitoring lies in its ability to provide managers with concrete evidence for causes of observed population trends. For instance, if a negative population trend is observed through sightability modeling and adult survival has declined in concert with the population, managers then have a starting point to investigate potential reasons for declines in adult survival, and possibly the population as a whole. The major drawback of demographic monitoring is the potentially large commitment of resources to monitoring efforts.

The integration of sightability modeling with demographic monitoring is a powerful approach to accurately inventory and monitor ferruginous hawk populations in Region 2. When implementing either approach singly or in tandem, there are some essential considerations. Sightability models should be developed using populations that are representative of the Region as a whole. This involves the inclusion of all of the primary nest substrates, habitat types, and topographies used by nesting ferruginous hawks within Region 2. Demographic monitoring should also include populations that are thought to represent the range of survival and productivity within Region 2, and include large enough sample sizes to reliably allow inferences to the entire Region 2 population.

Finally, although an inventory and monitoring program is a high priority for successful ferruginous hawk management by helping managers to determine how populations respond to management actions (or lack thereof), it should be remembered that simply counting hawks is not enough to conserve them. To conserve ferruginous hawks we need to understand and reduce limiting factors to their survival and reproduction.

Population management tools

As stated by Gillihan et al. (2004a), four main factors limit the breeding success of ferruginous hawks:

- ❖ availability and security of nest substrate
- ❖ disturbance to nesting pairs
- ❖ sufficient prey base
- ❖ unsuitability of habitat surrounding nest sites.

Accordingly, available and potential management tools have focused on these limiting factors and are discussed in a similar context.

Availability and security of nest substrate

Only 15 percent of 2,119 reported nest sites were located on the ground or dirt outcrops (Olendorff 1993), emphasizing the importance of elevated nest sites to ferruginous hawks. While 15 percent is a significant proportion of the total nests, no effective management tools exist to replace or provide new sites for nests located on the ground or on dirt outcrops. Fyfe and Armbruster (1977) reported that creation of ledges on cliffs or rimrock could provide additional nest sites in these locations. Where elevated nest structures (particularly trees) have been lost or are naturally lacking, artificial nest platforms can eliminate or significantly reduce the impact of this limiting factor. Artificial nest platforms have been installed in many areas with a paucity of suitable nest sites (Olendorff and Stoddart 1974, Howard and Hilliard 1980, Schmutz et al. 1984, Houston 1985, Stalmaster 1988, Call and Tigner 1991, Tigner et al. 1996). In Wyoming, up to 63 percent of available artificial nest structures were occupied in any given year (Tigner et al. 1996), and productivity of artificial nest sites may be higher than natural substrates (Schmutz et al. 1984, Tigner et al. 1996). Artificial nest sites provide more secure (both in stability of the actual nest and inaccessibility to mammalian predators), abundant, and potentially more productive nest substrates, making them an extremely valuable tool for managing local populations of ferruginous hawks.

Another valuable use of artificial nesting substrates is in mitigating losses of natural nest sites due to resource development (Tigner et al. 1996). Artificial nest structures may offset the loss of natural nest sites to development through more productive and secure nesting sites. In addition, naturally occurring nests, which would normally be lost to development or disturbance, can be moved to artificial nest platforms. Tigner et al. (1996) reported that nests in Wyoming were successfully moved from hazardous locations such as oil tanks and windmills.

Artificial nest platforms should not be placed within view of other *Buteo* nests, and they should be located far from human disturbance (<u>at least</u> 1 mile from any public road and at least 1.5 miles from any occupied building; Gillihan et al. 2004b). The following basic description of an artificial nest platform was adapted from Olendorff (1993) and Tigner et al. (1996). Nest platforms consist of either a wooden box (120 x 60 x 20 cm) with 2.54 cm welded wire mesh as the base, or a welded wire basket 60 to 90 cm in diameter and 20 cm deep. The box or basket is filled with nesting material representative of that found in the immediate area, and secured by fastening 2 to 4 branches across the top. The platform is attached to a pressure treated wooden pole (1.9 to 3.4 m tall) set 1 m in the ground. Juniper branches are nailed to the pole to simulate natural vegetation. Specific platform designs and other artificial platform considerations were provided by Schmutz (1983) and Tigner et al. (1996).

In addition to providing artificial nest substrates, existing or potential natural nest sites can be maintained, and even enhanced, using many techniques (Olendorff 1993). These include, but are not limited to, the following:

- ❖ rearranging the structure of existing nests to reduce the likelihood of falling or blowing down (Craig and Anderson 1979)

- ❖ reinforcing the bases of weak or unstable nests (Anderson and Follet 1978, Craig and Anderson 1979)
- ❖ stabilizing dead or dying nest trees (Olendorff 1993)
- ❖ placing artificial nests or wire baskets (Bohm 1977) in trees where natural tree nests have been lost (Fyfe and Armbruster 1977)
- ❖ fencing of actual or potential nest trees to protect them from cattle seeking shade or rubbing posts (Olendorff and Stoddart 1974)
- ❖ planting and protection of young trees to provide future nest sites (Olendorff and Stoddart 1974, Kochert et al. 1988)

Disturbance to nesting pairs

Nesting ferruginous hawks are extremely sensitive to disturbance, especially early in the reproductive period (Weston 1968, Olendorff 1973, Powers et al. 1975). Two types of management tools are available to protect breeding pairs from human disturbance: general and site specific tools (Olendorff 1993). General protection techniques include legislation of laws and regulations, enforcement of existing regulations, implementation of conservation easements, land swaps or acquisitions, and administrative closures or restrictions that benefit breeding ferruginous hawks.

Site-specific protection techniques include the following:

- ❖ if land treatments such as burning, plowing, and chaining need to be conducted within the breeding territory of a pair, delay these until the non-nesting season
- ❖ delay grazing until incubation is complete
- ❖ post "No Trespassing" signs or wildlife alert signs at least 450 m (Ensign 1983) from active nests
- ❖ close public land where ferruginous hawks are particularly susceptible to shooting
- ❖ inform local landowners, ranchers, and mine operators of the ecological value of ferruginous hawks and of their sensitivity to disturbance during the reproductive period (Gillihan et al. 2004a)
- ❖ if nests are in areas likely to be impacted by human activities, establish spatial buffer zones that exclude or restrict disturbances.

Gillihan et al. (2004b) provided guidelines for the degree of sensitivity to disturbance during different reproductive stages (**Table 6**, adapted from Romin and Muck 1999), and for duration and distance of different types of human disturbance to nesting pairs based on the reproductive stage (**Table 7**).

Table 6. Generalized ferruginous hawk nesting chronology, with sensitivity to disturbance at the nest site in relation to reproductive stage. This chronology represents long-term averages; variation occurs due to geographic variation across the species' range and annual variation in timing due to weather, prey availability, etc. Managers should use this only as a general guide. Decisions should rely on local information within Region 2 and knowledge of the breeding status of specific nests. From Gillihan et al. (2004b).

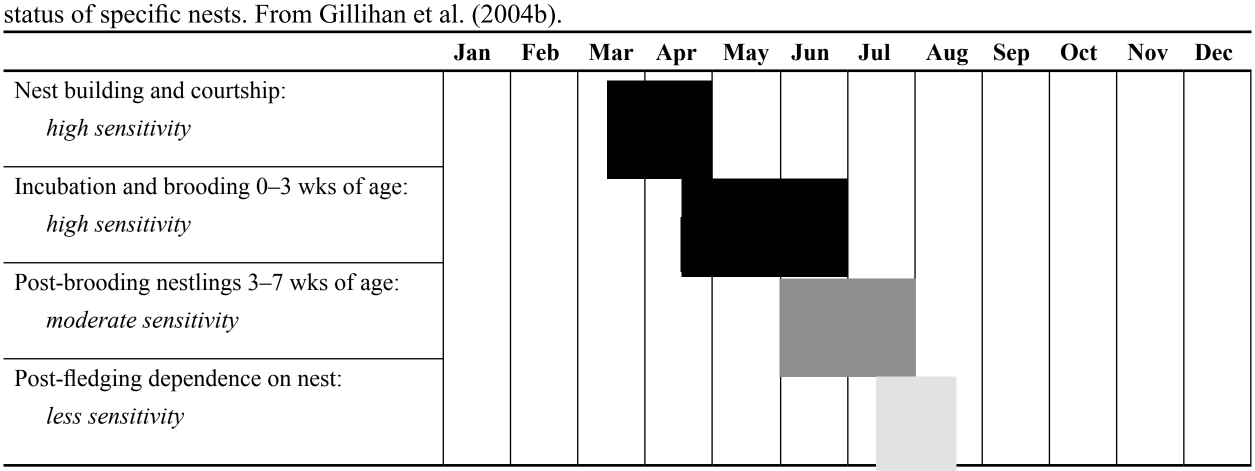


Table 7. Recommended maximum duration of disturbance by breeding stage, distance from nest, and disturbance type. "In-vehicle" disturbance includes any vehicle presence off-road or on dirt roads not routinely used for travel. "Out-of-vehicle" disturbance includes recreational activities (e.g., hiking, fishing, hunting) and work-related activities (e.g., mineral development, agricultural operations). From Gillihan et al. (2004b), adapted from Suter and Joness (1981), White and Thurow (1985), and Romin and Muck (1999).

	Distance from nest					
	0.0 – 0.5 mi		0.5 – 1.0 mi		1.0 – 1.5 mi	
	Disturbance type					
Sensitivity period	**In-vehicle**	**Out-of-vehicle**	**In-vehicle**	**Out-of-vehicle**	**In-vehicle**	**Out-of-vehicle**
High	<1 hr	none	<1 day	<1 hr	any	<1 day
Moderate	<1 hr	none	<1 day	<1 hr	any	<1 day
Less	<1 day	<1 hr	any	<1 day	any	any

Habitat management tools

Lack of sufficient prey base: Maintenance of a sufficient prey base is of extreme importance for conservation of ferruginous hawks, especially nesting pairs (Newton 1979, Wagner 1980, Olendorff 1993). In general, diverse and stable plant communities provide diverse and stable ferruginous hawk prey populations (Olendorff 1993). Therefore, if a lack of sufficient prey base is thought to be a threat to ferruginous hawks, the following techniques should be considered:

- ❖ Following land development activities (e.g., chaining, discing, burning or plowing) windrow brush to create cover, breeding habitat, and structural diversity for rodents, lagomorphs, and small birds.

- ❖ If chaining, discing, burning, or plowing must be done, conduct these activities outside of the ferruginous hawk reproductive period to avoid negative impacts to prey populations during this critical time.

- ❖ When reseeding disturbed areas, use seed mixtures that include locally obtained native seeds to promote vegetation diversity and vigor.

- ❖ If land conversion to a monoculture (e.g., crested wheatgrass) is unavoidable, leave a mosaic of treated (no more than 80 percent) and untreated (at least 20 percent) areas (Howard and Wolfe 1976).

- ❖ Encourage landowners to enroll in programs that offer incentives for maintaining or increasing prairie dogs (Gillihan et al 2004a).

- ❖ When deactivating utility lines, remove only the lines and leave poles in place. This increases hunting opportunities for ferruginous hawks.

- ❖ Manage the prey directly to increase it through planting of food plots, restricting or eliminating recreational shooting, etc. If small mammal control is unavoidable, reduce their numbers but do not eliminate them.

Some level of grazing is compatible with nearly all ferruginous hawk prey species and is certainly preferable to cultivation or urbanization. Grazing is a primary land use throughout most of the ferruginous hawk's range; the appropriate level of grazing depends upon the primary prey species in an area. Overgrazing is not desirable for any species (Olendorff 1993). In shortgrass prairie, black-tailed jackrabbits were least abundant in pastures with high grazing intensity during summer; desert cottontails (*Sylvilagus auduboni*) were most abundant in pastures moderately grazed during summer and winter; and white-tailed jackrabbits (*Lepus townsendii*) appeared unaffected by grazing intensity (Flinders and Hansen 1975). As Kochert (1989) reported, prey species that require a low level of cover are more favored by grazing than those that need substantial cover. The effects of grazing on ferruginous hawk prey species are quite variable (Olendorff 1993), presenting a challenge to managers charged with conserving not only ferruginous hawks, but intact, healthy, and functioning ecosystems. The best approach for dealing with this dilemma is to provide a landscape matrix consisting of a patchwork of different grazing intensities, from ungrazed to heavily grazed. Considerations include implementation of rest-rotation or deferred-rotation grazing regimes. Most important is the avoidance of overgrazing, which results in excessive soil compaction and erosion, invasion of noxious weeds and annual grasses, suppression of desired plant species, reduced abundances of ferruginous hawk prey species, and long-term deterioration of rangelands.

Unsuitability of habitat surrounding nest sites

If loss of suitable habitat surrounding nest sites is thought to be a threat, the following tools should be considered:

- ❖ use prescribed burning and let-burn policies to reduce the incidence of encroachment of woody species into grassland habitats and to create a diverse mosaic of grassland/shrub and scattered trees across the landscape
- ❖ maintain lands that have significant numbers of nesting ferruginous hawks in public ownership
- ❖ when considering land swaps, acquire land that is beneficial to ferruginous hawks
- ❖ work with landowners to remove crop insurance programs on marginal lands to encourage their return to permanent, native-dominated cover (Gillihan et al. 2004a)
- ❖ use conservation easements to conserve existing grasslands on private lands

Just as important as the above management techniques is the accurate inventory and monitoring of suitable ferruginous hawk habitat. A habitat suitability index (HSI) model exists for the ferruginous hawk (Jasikoff 1982). However, at the time it was created, the large amount of effort required to parameterize the model made its validation and application difficult at best. The model recognized 13 cover types valuable to ferruginous hawks, and each cover type required information regarding area of the cover type, mean height of the vegetative canopy, mean canopy cover, topographic diversity, availability of cliffs or rock outcrops, distance to suitable nest trees, and level of human disturbance. Fortunately, data for many of these variables are now available through the national Gap Analysis Program (GAP) and application of Geographic Information Systems (GIS). Using these recently developed tools, the HSI could now be applied to all of Region 2 in an effort to produce and validate a single habitat suitability model for the entire Region. If applied in conjunction with ferruginous hawk inventory and monitoring techniques described previously, this would aid greatly in understanding Region-wide patterns of ferruginous hawk distribution and abundance.

Information Needs

Throughout this document, knowledge of several aspects of ferruginous hawk ecology have been found wanting. The following discussion highlights important areas where gaps in knowledge exist and provides suggestions for potentially valuable fields of inquiry.

Survival

In a real-world management context there exist many more opportunities to positively affect productivity, compared to the few realistic and effective options for improving annual adult survival. Therefore, this assessment has focused primarily on providing insight into the tools and techniques available to improve productivity. However, survival, particularly of adults, was identified (in the sensitivity/elasticity analyses) as an important demographic parameter influencing ferruginous hawk population trends. Unfortunately, very limited information exists regarding annual or seasonal survival rates of ferruginous hawks. Recent work by Sillett and Holmes (2002) documented mortality estimates for a neotropical migrant songbird during migration that were 15 times higher than during the breeding season. Migration is probably also a particularly dangerous time for ferruginous hawks, and could be a significant factor affecting the annual mortality of both adults and juveniles. Studies utilizing telemetered individuals are rare, but they should be employed to obtain accurate estimates of ferruginous hawk survival during all seasons of the annual life cycle. Satellite telemetry would be particularly valuable, as ferruginous hawks are known to wander widely during migration. There is also a lack of information on the impact of power pole electrocution on ferruginous hawks that winter in heavily populated areas of California and Mexico. The impact to annual survival could be high, and needs further study (Cartron et al. 2000, Harmata et al. 2001). Other factors affecting survival also need further investigation, including secondary lead poisoning from varmint shooting, shooting of ferruginous hawks, and newly emergent diseases such as West Nile Virus.

Population monitoring

A pressing need for conservation of ferruginous hawks in Region 2, and throughout their range, is the implementation of a long-term, Region-wide inventory and monitoring program. Current estimates of abundance and population trends are based primarily on anecdotal observations or, at best, counts of breeding pairs in small geographic areas or Breeding Bird Surveys, the limitations of which have been discussed. The development and application of an inventory and monitoring program as described in the Conservation section would aid immensely in filling a vital gap in our current knowledge of ferruginous hawk ecology. A Region-wide inventory and monitoring program would especially aid in understanding the extent of nomadism during breeding, migration, and over-wintering. It would help to answer questions regarding the role of habitat conversion/loss to survival and productivity; how do we know that such habitat conversion/loss is not just causing hawks to move, rather than to die or suffer lowered productivity? What is the evidence that habitat conversion/loss is leading to population declines, not just range shifts?

Habitat modification

Throughout this document, we have attempted to emphasize the correlation between prey abundance and ferruginous hawk abundance and productivity. Because the condition of prey habitat is the primary determinant of prey abundance, experimental studies are needed that examine the influence of different land management activities on prey populations, and thus, on ferruginous hawks. The indirect effects of habitat modification on prey populations are not well understood. The degree to which landscape modifications affect black-tailed prairie dog populations (a major ferruginous hawk food source in Region 2) across its range is largely unknown. Better understanding of how landscape modifications affect rodent and other small mammal populations will enable managers to better plan reliable habitat restoration and conservation programs that will ultimately benefit ferruginous hawks.

Movement patterns

Significant gaps exist regarding the migration patterns of ferruginous hawks, especially those that breed at the southern extent of the species' range (Gillihan et al. 2004a). Are these populations sedentary because of stability of prey populations? In addition, little is known about the winter ecology of birds that migrate to Mexico, or about gender or age-related factors affecting migration. Almost nothing is known about the extent of juvenile dispersal, breeding dispersal, or nomadism from one year to the next. Satellite based tracking transmitters have recently become feasible for use with ferruginous hawks and provide the ideal means to investigate movement patterns and survival over the very large areas used by ferruginous hawks (Watson 2003).

Human disturbance

Ferruginous hawks are quite sensitive to human disturbance during the reproductive period, especially during early incubation. Because they are a species of special conservation interest in many areas and may be the focus of intense research, the influence of scientific study itself on ferruginous hawks merits investigation (Olendorff 1993). How do factors such as food availability, accessibility of the nest, and field techniques of researchers influence nest desertion or productivity?

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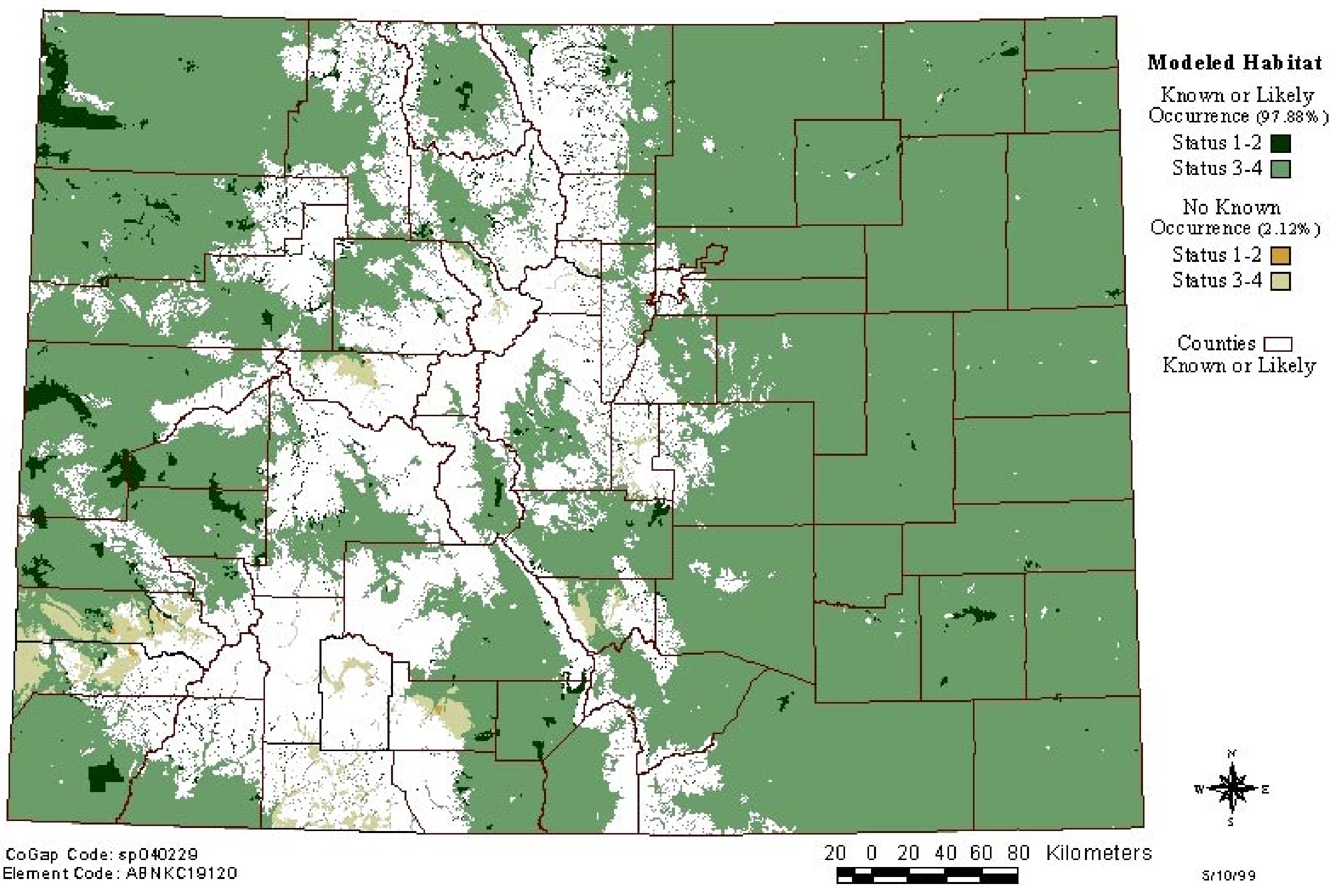
APPENDIX

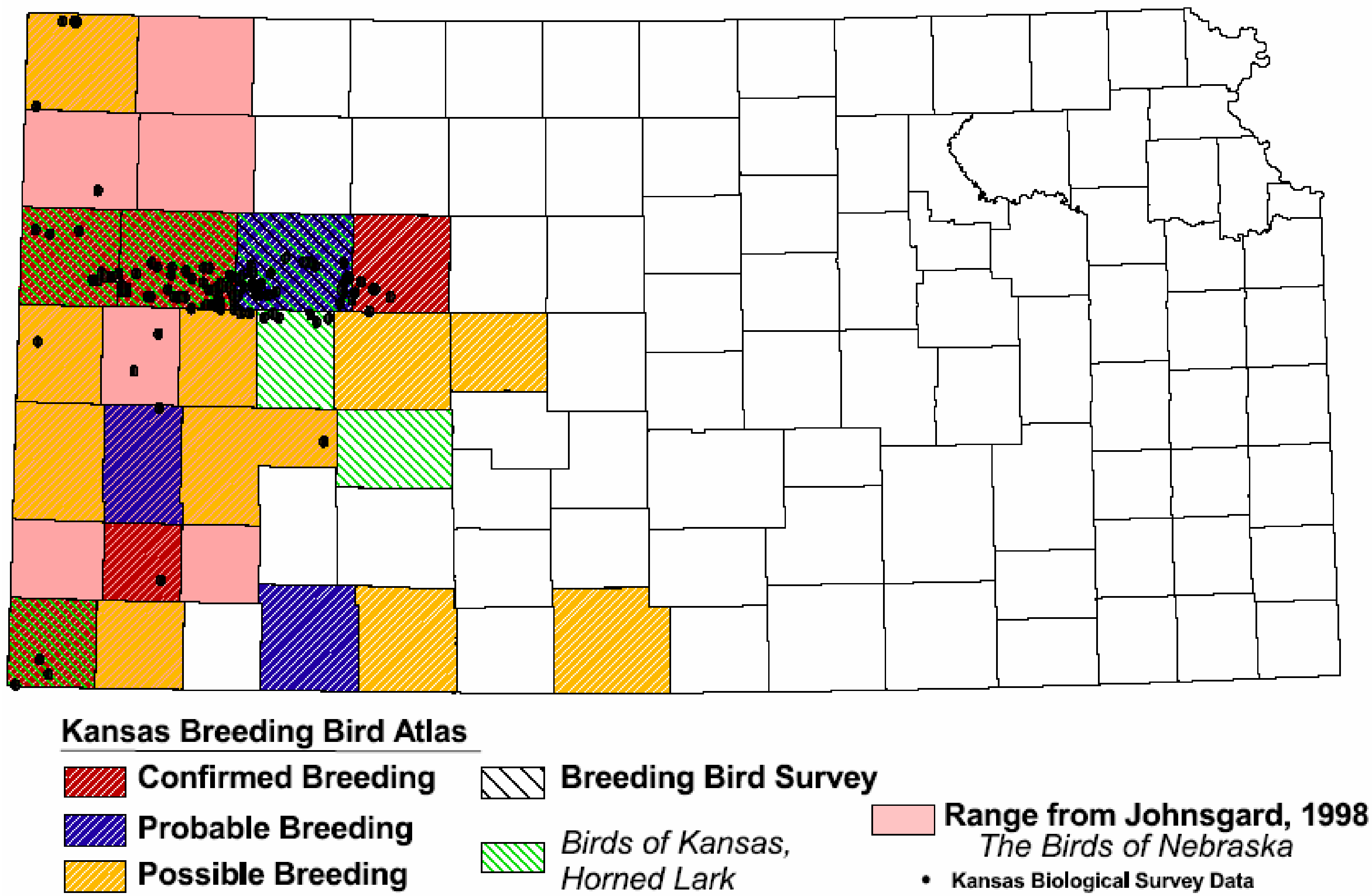
Distribution of ferruginous hawks or potential habitats in Colorado, Kansas, South Dakota, and Wyoming from Gap analysis.

Colorado Gap Analysis Project
Ferruginous Hawk (*Buteo regalis*)[A]

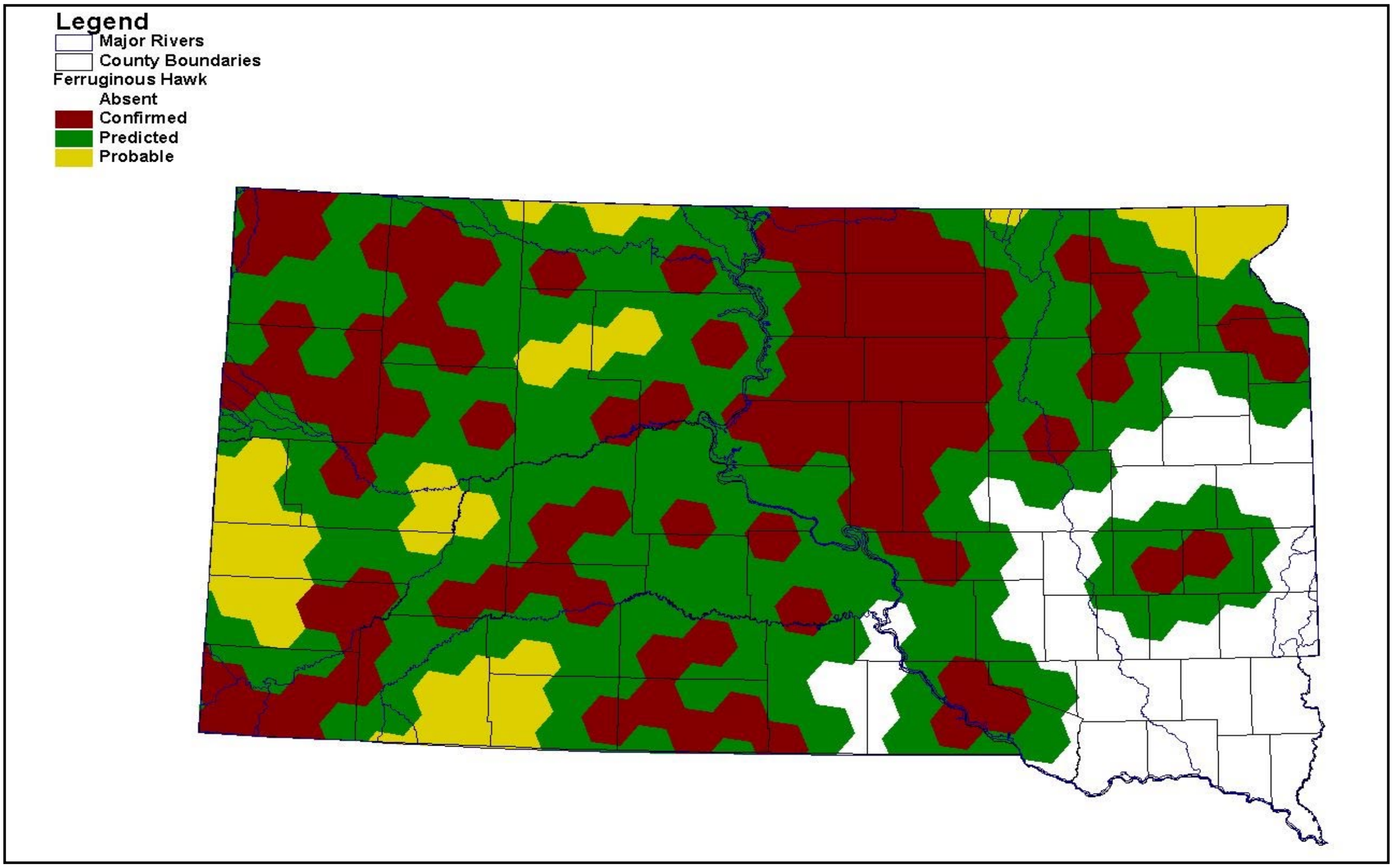


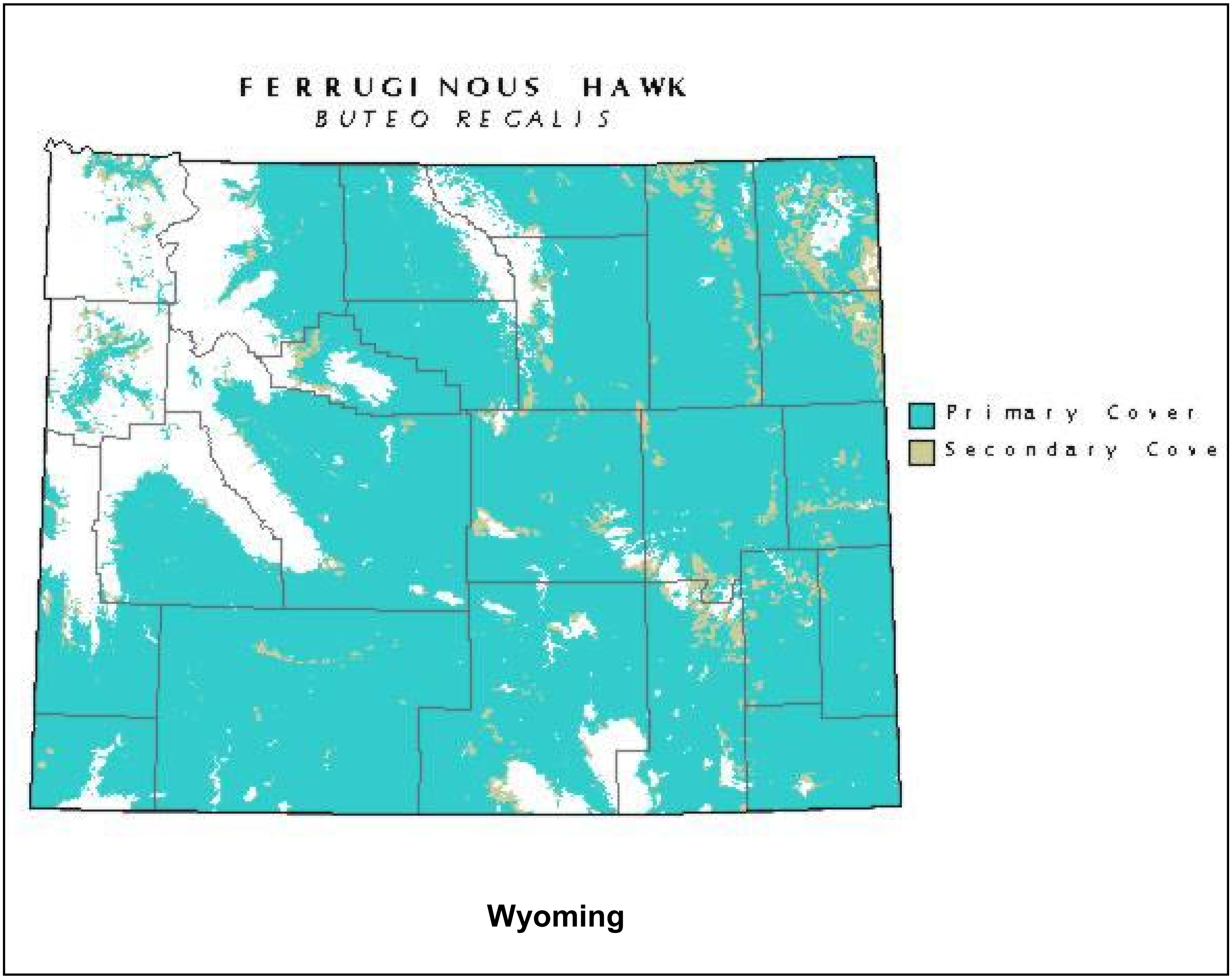
[A]See Table 4.1, in Colorado Gap Analysis Project Report http://ndis1.nrel.colostate.edu/cogap/report/cgrptALL.pdf for Status Code Descriptions.

Ferruginous Hawk



South Dakota
DRAFT - Ferruginous Hawk




FERRUGINOUS HAWK
BUTEO REGALIS
Primary Cover
Secondary Cove
Wyoming

LIST OF ERRATA

2/6/06 Figure 2. Changed credit of authors to Light morph ferruginous hawk, photograph by Alejandro Bravo and dark morph ferruginous hawk, photograph ©Mark Chappell.