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The Effects of Management Practices on Grassland Birds—Ferruginous Hawk (*Buteo regalis*)

Chapter N of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–N

U.S. Department of the Interior
U.S. Geological Survey

Cover. Ferruginous Hawk. Photograph by David O. Lambeth, used with permission.
Background photograph: Northern mixed-grass prairie in North Dakota, by Rick Bohn, used with permission.

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By Jill A. Shaffer,[1] Lawrence D. Igl,[1] Douglas H. Johnson,[1] Marriah L. Sondreal,[1] Christopher M. Goldade,[1,2] Amy L. Zimmerman,[1] Jason P. Thiele,[1,3] and Betty R. Euliss[1]

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The Effects of Management Practices on Grassland Birds

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U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey
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Figure

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Abbreviations

n.d. no date

spp. species (applies to two or more species within the genus)

Acknowledgments

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Capsule Statement

Keys to Ferruginous Hawk (*Buteo regalis*) management are providing suitable nest sites, protecting active nest areas from human disturbance, and providing suitable habitat for prey. Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).

Breeding Range

Ferruginous Hawks breed from northeastern Washington, southern Alberta, southern Saskatchewan, and southwestern Manitoba; south to eastern Oregon, western Nevada, southern California, and northern Arizona; and east through northern Texas, western Oklahoma, and eastern North Dakota (National Geographic Society, 2011). The relative densities of Ferruginous Hawks in the United States and southern Canada, based on North American Breeding Bird Survey data (Sauer and others, 2014), are shown in figure N1 (not all geographic places mentioned in report are shown on figure). Two subpopulations of Ferruginous Hawk are recognized (Ng and others, 2017).

Ferruginous Hawk. Illustration by Patsy Renz, used with permission.

Suitable Habitat

Ferruginous Hawks prefer open grasslands and shrubsteppe communities. They use native and tame grasslands, pastures, hayland, cropland, deserts, riparian areas, irrigated agriculture, and shrubsteppe (Stewart, 1975; Woffinden, 1975; Powers and Craig, 1976; Fitzner, and others, 1977; Blair, 1978; Wakeley, 1978; Johnsgard, 1979; Lardy, 1980; Schmidt, 1981; Gilmer and Stewart, 1983; Green and Morrison, 1983; Konrad and Gilmer, 1986; Kimsey and Conley, 1988; MacLaren and others, 1988; Palmer, 1988; Roth and Marzluff, 1989; Bechard and others, 1990; Black, 1992; Leslie, 1992; Niemuth, 1992; Faanes and Lingle, 1995; Houston, 1995; Zelenak and Rotella, 1997; Leary and others, 1998; McConnell and others, 2008; Ng and others, 2017). Ferruginous Hawks usually occupy rolling or rugged terrain (Blair, 1978; Gilmer and Stewart, 1983; Palmer, 1988; Black, 1992; Keough and Conover, 2012). High elevations, forest interiors, narrow canyons, and cliffs are avoided (Janes, 1985; Palmer, 1988; Black, 1992), as is parkland habitat in Canada (Schmutz, 1991a). Landscapes with moderate coverage (less than [<] 50 percent) of cropland and hayland are used for nesting and foraging (Blair, 1978; Wakeley, 1978; Gilmer and Stewart,

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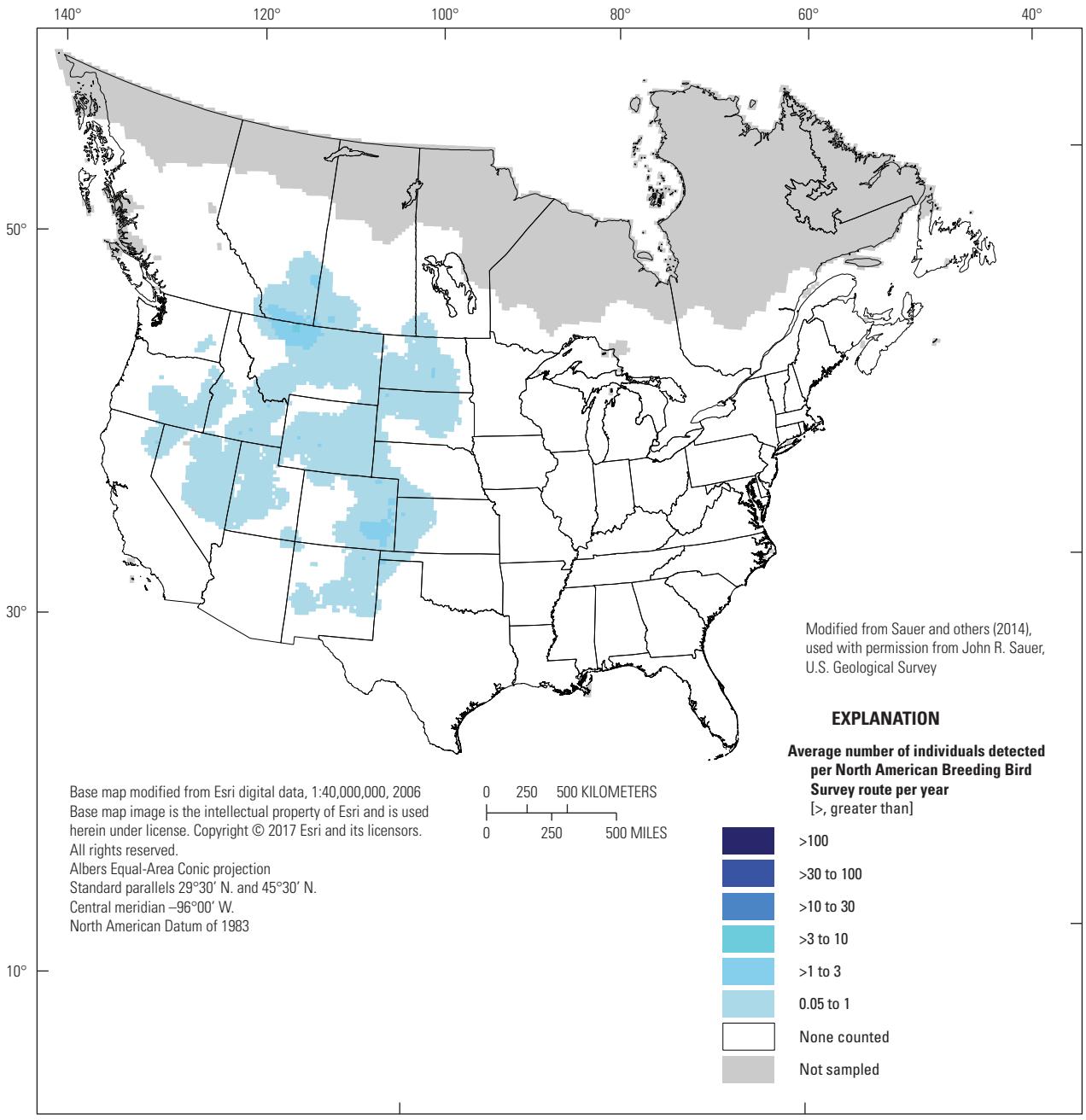

Figure N1. Breeding distribution of the Ferruginous Hawk (*Buteo regalis*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

1983; Konrad and Gilmer, 1986; Schmutz, 1989, 1991a; Bechard and others, 1990; Faanes and Lingle, 1995; Leary and others, 1998), although near the edges of the breeding range, the species occupies nesting territories that are predominantly cropland (De Smet and Conrad, 1991). In California, Idaho, Oregon, and Utah, the species preferred areas that had few perches; mean percentage of home ranges with no perches was 77.3 percent of 50 pairs (Janes, 1985). In Idaho, most nest trees were more than 1 kilometer (km) from an adjacent tree (Hansen, 1994).

Ferruginous Hawks are opportunistic in their selection of nest sites (Olendorff, 1973; Woffinden, 1975; Gilmer and Stewart, 1983; MacLaren and others, 1988; Zelenak and Rotella, 1997). Historically, most of the nests were on or near the ground (dirt/rock/chalk outcrops, riverbed mounds, mud buttes, and rock piles); more recently, many nests were built in trees and large shrubs or on utility structures, artificial platforms, roofs of abandoned buildings, haystacks, and river cutbanks (Davy, 1930; Weston, 1968; Olendorff, 1973; Stewart, 1975; Woffinden, 1975; Lokemoen and Duebbert,

1976; Fitzner and others, 1977; Blair, 1978; Smith and Murphy, 1978, 1982; Johnsgard, 1979; Lardy, 1980; Blair and Schitoskey, 1982; Houston, 1982, 1985; Gilmer and Stewart, 1983; Woffinden and Murphy, 1983; Ratcliffe and Murray, 1984; Schmutz, 1984, 1987, 1991a; Gaines, 1985; MacLaren and others, 1988; Palmer, 1988; Roth and Marzluff, 1989; Bechard and others, 1990; Phillips and Beske, 1990; De Smet and Conrad, 1991; Atkinson, 1992; Black, 1992; Leslie, 1992; Niemuth, 1992; Steenhof and others, 1993; Faanes and Lingle, 1995; Zelenak and Rotella, 1997; McConnell and others, 2008; Keough and Conover, 2012; Kennedy and others, 2014; Ng and others, 2017).

Nest-site selection depends on available substrates. Ground nests typically are located far from human activities and on elevated landforms in large grassland areas (Lokemoen and Duebbert, 1976; Blair, 1978; Blair and Schitoskey, 1982; Gilmer and Stewart, 1983; Atkinson, 1992; Black 1992). Lone or peripheral trees are preferred as nesting substrates more than trees in densely wooded areas (Weston, 1968; Rising, 1974; Lokemoen and Duebbert, 1976; Johnsgard, 1979; Gilmer and Stewart, 1983; Woffinden and Murphy, 1983; Palmer, 1988; Bechard and others, 1990; De Smet and Conrad, 1991; Leslie, 1992; Hansen, 1994; McConnell and others, 2008). Many tree species have been used as nesting substrates, including oneseed juniper (*Juniperus monosperma*), Utah juniper (*Juniperus osteosperma*), honey locust (*Gleditsia triacanthos*), black cottonwood (*Populus trichocarpa*), eastern cottonwood (*Populus deltoides*), mulberry (*Morus* spp.), osage orange (*Maclura pomifera*), boxelder (*Acer negundo*), Russian olive (*Elaeagnus angustifolia*), peachleaf willow (*Salix amygdaloides*), green ash (*Fraxinus pennsylvanica*), quaking aspen (*Populus tremuloides*), and elm (*Ulmus* spp.) (Rising, 1974; Schmidt, 1981; Gilmer and Stewart, 1983; De Smet and Conrad, 1991; De Smet, 1992; Leslie, 1992; Faanes and Lingle, 1995; McConnell and others, 2008; Keough and Conover, 2012; Coates and others, 2014; Kennedy and others, 2014). In Manitoba, average nesting success (69 percent) and number of young fledged per initiated nest (1.96) were higher in 67 nests in cottonwood and aspen trees (*Populus* spp.) than in 93 nests in other species of trees or shrubs (44 and 1.19 percent, respectively) (De Smet, 1992). Ferruginous Hawks may nest on anthropogenic structures, such as artificial nest platforms and electrical transmission towers (Coates and others, 2014). In a Wyoming study, daily nest survival rate and fledgling production were greater for nests on anthropogenic structures (that is, artificial nest platforms, gas condensation tanks, abandoned windmill platforms, power poles) than on natural substrates (that is, trees, cliffs, rock outcrops) (Wallace and others, 2016).

Nest-site selection also depends on surrounding land use and prey availability. Tree-nesting Ferruginous Hawks seem to be less sensitive to surrounding land use, but they still avoid areas of intensive agriculture or high human disturbance (Howard and Wolfe, 1976; Gilmer and Stewart, 1983; Schmutz, 1984, 1987, 1991a; Bechard and others, 1990; Leslie, 1992; Hansen, 1994; Faanes and Lingle, 1995), except perhaps where human-related disturbances increase prey abundance (Schmutz, 1989; De Smet and Conrad, 1991; Zelenak and Rotella, 1997; Keough and Conover, 2012). In North Dakota, pastures and hayland made up 95 percent of the land around ground nests and 76.5 percent of the land around tree nests (Gilmer and Stewart, 1983). In another North Dakota study, Gaines (1985) reported that Ferruginous Hawks preferred to nest in areas dominated by pastures and hayland. Also in North Dakota, native pastures and hayfields were the habitats most often used by fledglings and adults, whereas cultivated fields rarely were used (Konrad and Gilmer, 1986). In contrast, in Manitoba, 78 percent of nests had more than 30 percent cultivated land within 2 km, 20 percent had more than 50 percent cultivation, and 6–9 percent were surrounded by more than 75 percent cultivation (De Smet and Conrad, 1991). In Wyoming, breeding territories with greater shrub cover produced more fledglings, whereas prey abundance had no effect on nest survival or fledgling production (Wallace and others, 2016). In Nebraska, the number of fledglings produced in unfragmented rangeland was not significantly different from the number of fledglings produced in a mixture of rangeland and cropland (Podany, 1996). In eastern Colorado, Ferruginous Hawks nested more frequently in grassland areas than in cultivated areas (Olendorff, 1973; Leslie, 1992). In western Kansas, most nests were surrounded by at least 50 percent rangeland and 25–50 percent cropland, although the territory of one pair included more than 75 percent cropland (Roth and Marzluff, 1989). In Utah, Idaho, Oregon, and California, Ferruginous Hawks preferred native grassland and shrubland habitats over cropland (mean percentages of grassland and shrubland in home ranges were 51 and 31.5 percent, respectively) and preferred areas with no perches (Janes, 1985). In Idaho, breeding productivity was greater in territories with more fields of crested wheatgrass (*Agropyron cristatum*) interspersed with desert shrub than in territories with monotypic stands of crested wheatgrass or shrubland, or with greater amounts of Utah juniper, alfalfa (*Medicago sativa*), or cropland (Howard, 1975). In northern Montana, ground nests were located in grass-dominated, rolling (greater than [>] 10 percent slope) rangeland; in general, cropland and areas with dense (>30 percent cover), tall (>15.2 centimeters [cm]) sagebrush (*Artemisia* spp.) were avoided (Black, 1992). In Oregon, nest areas were characterized by a lack of shrub cover (Lardy, 1980); however, in southwestern Montana, sagebrush and grasslands predominated within 100 meters (m) of nests (Atkinson, 1992). In Washington, some nests were in agricultural fields, but most nests were in areas with higher percentages of grassland, shrubland, and western juniper (*Juniperus occidentalis*) (Bechard and others, 1990).

Nest-site selection usually is related to prey availability in that Ferruginous Hawks often nest near areas with abundant prey. In north-central Montana landscapes with 80 percent grasslands and 20 percent agricultural lands, nests closer to cultivated fields and to roads were more successful than nests farther away from these habitats, presumably because prey densities were higher near edge habitats (Zelenak and

Rotella, 1997). In Alberta, prey abundance increased as the area of cultivation increased up to 30 percent (of 4,100-hectare [ha] plots), but prey abundance was reduced where agricultural land use exceeded 30 percent (Schmutz, 1989). Nest density of Ferruginous Hawks was higher in landscapes with 11–30 percent cultivation than in landscapes with <11 percent cultivation. In Utah, nest locations were associated with high numbers of black-tailed jackrabbits (*Lepus californicus*) and white-tailed prairie dogs (*Cynomys leucurus*), but also with the higher number of and proximity to active oil and gas wells (Keough and Conover, 2012). Keough and Conover (2012) surmised that the watering activities associated with the wells enhanced habitat conditions for prey species in an otherwise xeric landscape. In another Utah study, nest sites occurred near cover that was suitable for black-tailed jackrabbits (Woffinden, 1975). In Idaho and Saskatchewan, foraging Ferruginous Hawks required large pastures in which Townsend's or Richardson's ground squirrels (*Urocitellus townsendii* and *Urocitellus richardsonii*, respectively) were abundant (Wakeley, 1978; Houston and Bechard, 1984). In western Kansas, however, more of the nests (86 of 99) were not in direct view of black-tailed prairie dog (*Cynomys ludovicianus*) towns, although most nest sites were within 8 km of towns (Roth and Marzluff, 1989). In Washington, when prey densities were low in big sagebrush-grassland habitat, agricultural fields served as important foraging areas (Leary and others, 1998). Ferruginous Hawks foraged extensively in alfalfa and irrigated potato fields in Washington and in alfalfa fields in Idaho during the breeding season, presumably because of high prey densities (Wakeley, 1978; Leary and others, 1998). In South Dakota, fledglings hunted in an area where native hay recently had been cut (Blair, 1978). In one of two areas within shortgrass prairies in New Mexico, Ferruginous Hawk nests occurred closer to Gunnison's prairie dog (*Cynomys gunnisoni*) towns than expected based on habitat availability (Cook and others, 2003). The number of young fledged per nest was greater at nests <2 km from prairie dog towns than at nests >2 km from prairie dog towns.

The height and orientation of Ferruginous Hawk nests were relatively similar across the species' range, but nest location or nest substrate may affect nesting success. In Manitoba, the mean height of 43 nests was 6.5 m, but nests in cottonwoods were considerably higher (10.5 m) and were often situated on tree limbs rather than in a major fork (De Smet and Conrad, 1991). In South Dakota, the mean height of buttes or hills on which 21 ground nests were built was <10 m above the surrounding prairie; nests were oriented toward the south and west, providing access to prevailing winds from those directions (Blair, 1978). In South Dakota, Lokemoen and Duebbert (1976) reported that 12 ground nests were oriented toward the west. In southwestern Montana, 40 of 50 nests were oriented toward the south (Atkinson, 1992). Thirty-two nests were built on rock outcrops; other nests were built on the ground, on rimrock, on cliffs, in trees, or on power line towers. Of the 50 nests, slope averaged 62.8 percent, and the nests were on the upper 35 percent of the slope. In North Dakota, most ground nests were on slopes near hillcrests or ridgetops (Johnsgard, 1979). In northern Montana, 29 ground nests were located either on the tops of small rises or on slopes ranging from 10 to 50 percent (Black, 1992). Average vertical distance of ground nest sites below the highest surrounding topographic feature was 10 m, whereas average height of ground nest sites above the valley floor was 10.4 m, indicating that nests were placed at mid-elevation sites within the immediate topography. In Wyoming, the mean slope of 23 nest sites was 14.26 degrees (°), and the mean height of nests was 4.55 m (MacLaren and others, 1988). Nest trees had a diameter of 34.3 cm at breast height and were 5.51 m tall; nests averaged 0.34 km from water and 0.44 km from the nearest road. In North Dakota, 45 percent of 61 nests were ground nests in native prairie, 29 percent were in trees, 12 percent were on large boulders or rock piles, 12 percent were on hay or straw stacks, and 2 percent were situated on the straw-covered roof of an abandoned stable (Stewart, 1975). In eastern Colorado, the mean height of 21 nest trees was 10.3 m (Leslie, 1992). In western Kansas, nests were placed on ledges 2–3 m high (Rising, 1974). In Manitoba, nests placed higher above the ground were more successful than nests placed lower; of 59 nests >8 m above the ground, 69 percent were successful, compared to 58 percent of 57 nests 5–8 m above the ground and 42 percent of 59 nests <5 m above the ground (De Smet, 1992). In southeastern Washington, 86 percent of 29 nests on outcrops or in western junipers were located <10 m above the ground and had southern or western exposures (Bechard and others, 1990). In Oregon shrubsteppe, 17 nests were in short (mean=4.8 m) western juniper trees, were <10 m above the ground, and had large support branches (Green and Morrison, 1983). In Washington, Idaho, and Utah, several studies revealed that nests were <10 m above the ground in western juniper or Utah juniper trees (Howard, 1975; Woffinden, 1975; Howard and Wolfe, 1976; Powers and Craig, 1976; Fitzner and others, 1977; Smith and Murphy, 1978; Woffinden and Murphy, 1983; Hansen, 1994). In Utah, nests were constructed 2–3 m above the ground, were most commonly located on the sides or summits of hills, and often had southern or eastern exposures (Weston, 1968). In another Utah study, Woffinden (1975) determined that the average slope for hills on which 19 outcrop nests were placed was 43°, whereas the average slope of hills for the 16 trees harboring nests was 27°.

Ferruginous Hawks are easily disturbed during the breeding season (Olendorff, 1973; Gilmer and Stewart, 1983; Schmutz, 1984; White and Thurow, 1985; Bechard and others, 1990; Leslie, 1992; Hansen, 1994). The species is prone to nest abandonment, particularly during the early stages of the nesting cycle (Davy, 1930; Weston, 1968; Fitzner and others, 1977; Gilmer and Stewart, 1983; White and Thurow, 1985). Sensitivity to human disturbance may be heightened in years of low prey abundance (White and Thurow, 1985).

Nesting success may be reduced at nests built close to human activity, and Ferruginous Hawks may avoid nesting near buildings. In South Dakota, the probability of fledging young was 11.4 percent greater in more remote nests than in

nests within 2.47 km of occupied buildings (Blair, 1978). In eastern Colorado, nests in remote locations had greater productivity than nests in more accessible locations (Olendorff, 1973). In Alberta, Ferruginous Hawks rarely nested within 0.5 km of farmyards (Schmutz, 1984). In North Dakota, Ferruginous Hawks avoided cropland and nesting within 0.7 km of occupied buildings (Gaines, 1985). In some cases, Ferruginous Hawks may be more tolerant of human disturbances. In Manitoba where roads were prevalent in Ferruginous Hawk range, 75 percent of nests were within 0.8 km of a road, including 10 percent within 0.1 km (De Smet and Conrad, 1991). Nesting has occurred near active railroads and gravel roads (Rolfe, 1896; Gilmer and Stewart, 1983; MacLaren and others, 1988). In Utah, occupied nests were associated with areas with high numbers of active oil and gas wells within a 4-km radius of nest sites (Keough and Conover, 2012).

Nesting success may be influenced by weather events. Wallace and others (2016) examined the effect of minimum and maximum daily temperature, total daily precipitation, and number of June days with severe storm events on daily nest survival rate and fledgling productivity. Number of storms negatively affected fledgling production; the other variables had no impact.

Prey Habitat

Ferruginous Hawk densities and productivity are closely associated with cycles of prey abundance (Woffinden, 1975; Powers and Craig, 1976; Smith and Murphy, 1978; Smith and others, 1981; Gilmer and Stewart, 1983; Houston and Bechard, 1984; White and Thurow, 1985; Palmer, 1988; Schmutz, 1989, 1991a; Schmutz and Hungle, 1989; Poulin and others, 2001; Schmutz and others, 2008; Ng and others, 2017). Mammals are the primary prey during the breeding season, although birds, amphibians, reptiles, and insects also are taken (Weston, 1968; Howard, 1975; Fitzner and others, 1977; Blair, 1978; Smith and Murphy, 1978; Gilmer and Stewart, 1983; Palmer, 1988; De Smet and Conrad, 1991; Atkinson, 1992; Hansen, 1994; Giovanni and others, 2007; Schmutz and others, 2008). Primary prey items in grasslands east of the Rocky Mountains are ground squirrels (*Urocitellus* spp.), followed by eastern pocket gophers (*Geomys* spp.) and white-tailed jackrabbits (*Lepus townsendii*) (Olendorff, 1993; Ng and others, 2017). Primary prey items in western shrubsteppe are jackrabbits (*Lepus* spp.), followed by ground squirrels and pocket gophers (Smith and Murphy, 1978; Olendorff, 1993; Ng and others, 2017). White- and black-tailed prairie dogs also serve as prey items (Powers and Craig, 1976; MacLaren and others, 1988; Giovanni and others, 2007).

In moderately cultivated areas of north-central Montana, active burrow counts of Richardson's ground squirrels were higher along the edges of agricultural fields than in grasslands (Zelenak and Rotella, 1997). In Oregon, Janes (1985) determined that the highest abundances of major prey species (white-tailed jackrabbits, Townsend's ground squirrels, and northern pocket gophers [*Thomomys talpoides*]) occurred in native grasslands. In Utah and Idaho, black-tailed jackrabbits were associated with sagebrush and preferred tall cover and open spaces (Westoby and Wagner, 1973; Janes, 1985). Black-tailed jackrabbits that were foraging in crested wheatgrass fields in Utah and Idaho concentrated their activity within 300 m of field edges (Westoby and Wagner, 1973). Townsend's ground squirrels in Idaho were most abundant in grass-shrub vegetation in areas free from disturbance, especially plowing, but also were observed in oldfields (idle or neglected arable lands that have naturally reverted back to perennial cover), pastures, and crested wheatgrass fields (Wakeley, 1978). Northern pocket gophers were most common in alfalfa fields. Keeley and others (2016) examined the difference in Ferruginous Hawk diet between rural and exurban (that is, semi-rural land use characterized by low housing density of more than 2 ha per housing unit) grasslands in New Mexico. Ferruginous Hawks in both areas consumed Botta's pocket gopher (*Thomomys bottae*), Gunnison's prairie dog, and desert cottontail (*Sylvilagus audubonii*), but hawks in exurban grasslands consumed more prairie dogs, whereas hawks in rural grasslands consumed more lagomorphs. The exurban hawks had greater nest success and productivity than did rural hawks.

Visibility of prey also is an important factor to consider in assessing habitat suitability because Ferruginous Hawks avoid dense vegetation that reduces their ability to see prey (Howard and Wolfe, 1976; Wakeley, 1978; Schmutz, 1987). Prey vulnerability decreases where taller small-grain crops replace shorter grasses (Houston and Bechard, 1984).

Area Requirements and Landscape Associations

In Nebraska and North Dakota, Ferruginous Hawks preferred large blocks of native prairie (Stewart, 1975; Faanes and Lingle, 1995). Estimates of home-range size ranged from 3.14 to 8.09 square kilometers (km^2) in the Columbia River Basin and Great Basin regions of the Western United States (Smith and Murphy, 1978; Janes, 1985; Olendorff, 1993). The average home-range size for Ferruginous Hawks was 90.3 km^2 in Washington, and the variability in home range was significantly related to distance from the nest to the nearest irrigated agricultural field (Leary and others, 1998). One male that nested closest to the surrounding agricultural fields had the smallest home range, whereas a male that nested farthest from the agricultural fields had the largest home range. In southwestern Montana, average distance between eight active nests was 1.9 km (Atkinson, 1992). In Utah, occupied nest sites were associated with the presence of other occupied raptor nests within 2–3.5 km (Keough and Conover, 2012). In Idaho, a pair may require an area of up to 21.7 km^2 for hunting (Wakeley, 1978).

Brood Parasitism by Cowbirds and Other Species

The Ferruginous Hawk is an accidental but unsuitable host of the Brown-headed Cowbird (*Molothrus ater*), an obligate brood parasite (Friedmann, 1929). There is one published record of cowbird parasitism in a Ferruginous Hawk nest (A. Eastgate, pers. commun. [n.d.] in Friedmann, 1929; Shaffer and others, 2019).

Breeding-Season Phenology and Site Fidelity

Ferruginous Hawks occur in breeding areas from late February through early October (Weston, 1968; Olendorff, 1973; Maher, 1974; Blair, 1978; Smith and Murphy, 1978; Gilmer and Stewart, 1983; Schmutz and Fyfe, 1987; Palmer, 1988; Ng and others, 2017). Renesting within the same year is rare (Woffinden, 1975; Palmer, 1988). Territory and nest-site fidelity is common for Ferruginous Hawks, and one of several nests within a territory may be used in alternate years (Davy, 1930; Weston, 1968; Olendorff, 1973; Blair, 1978; Smith and Murphy, 1978; Palmer, 1988; Roth and Marzluff, 1989; Schmutz, 1991b; Atkinson, 1992; De Smet, 1992; Houston, 1995). Nest reoccupancy may be affected by nest success; in Manitoba, 52 percent of 71 successful nests were reused compared to 14 percent of 63 unsuccessful nests (De Smet, 1992). In Wyoming, elevated nests were used in consecutive years more often than were ground nests (Phillips and Beske, 1990). Mate fidelity also is common (Schmutz, 1991b).

Species' Response to Management

In Idaho, Ferruginous Hawks readily nested in areas burned within the past 15 years, as well as in unburned areas (Lehman and others, 1996). In south-central Washington, nests occurred in recently burned sagebrush/cheatgrass (downy brome [*Bromus tectorum*]) habitat (Leary and others, 1998).

Grazing benefits Ferruginous Hawks by reducing vegetation cover and making prey more visible (Wakeley, 1978; Konrad and Gilmer, 1986). Kantrud and Kologiski (1982) found the highest densities of Ferruginous Hawks in heavily grazed areas in the northern Great Plains. These areas provided a combination of grazing and soil type (typic borolls) that resulted in abundant prey populations. In South Dakota, Ferruginous Hawks preferentially placed ground nests in lightly grazed pastures or idle areas (Lokemoen and Duebbert, 1976; Blair, 1978; Blair and Schitoskey, 1982). In Saskatchewan, preferred grassland habitat exists in large blocks of government pastures located along the Montana and Alberta borders (Houston and Bechard, 1984). These blocks of habitat were the only remaining areas with stable Ferruginous Hawk populations in Saskatchewan. Livestock, however, can weaken nest trees by excessive rubbing or trampling (Houston, 1982; Olendorff, 1993). In Oregon, the presence of aspens within bunchgrass prairie was a strong predictor of Ferruginous Hawk occupancy, but aspen trees were heavily grazed by cattle; continued grazing pressure on unprotected stands of aspen trees could decrease availability of aspens as nesting structures for Ferruginous Hawks (Kennedy and others, 2014). Bock and others (1993) suggested that Ferruginous Hawks would respond negatively to grazing in shrubsteppe habitats, based on the ground-cover requirements of their prey.

Conversion of grasslands to intensive cultivation has reduced the amount of preferred habitat that is available to Ferruginous Hawks and has been implicated in the population decline of the species in some areas (Schmutz, 1984; Faanes and Lingle, 1995). Intensive agricultural practices, such as annual plowing and biennial fallowing, exclude many prey species (Wakeley, 1978; Houston and Bechard, 1984). Agricultural development has restricted the species to areas of greater topographic relief or other areas unsuitable for agriculture (Stewart, 1975). In Alberta, areas with >50 percent cultivation were not used by Ferruginous Hawks (Schmutz, 1984, 1991a). In Alberta, nesting densities of Ferruginous Hawks increased as the percentage of cultivation on plots increased to 30 percent and then declined as the percentage of cultivation on plots continued to increase (Schmutz, 1989). Conversely, in Manitoba, productivity was not adversely affected by proximity of nests to agriculture; successful nests were surrounded by more cultivated land and less pasture than failed nests (De Smet and Conrad, 1991). Of 43 nests, 77 percent had >30 percent cultivation within 2 km. In Idaho, the species foraged in areas containing bare ground and pastures significantly more than expected by chance (Wakeley, 1978).

Exposure to pesticides and lead is detrimental to Ferruginous Hawks. In a continent-wide survey, three Ferruginous Hawks were determined to have been killed by pesticide abuse (use of a pesticide outside of its approved application) (Mineau and others, 1999). Of 46 eggs collected in North Dakota and South Dakota during a 4-year period in the 1970s, 85 percent contained residues of dichlorodiphenyldichloroethylene (DDE), 11 percent contained residues of dieldrin, 43 percent contained residues of heptachlor epoxide, 17 percent contained residues of ocychlordane, 22 percent contained residues of hexachlorobenzene, and 15 percent contained residues of polychlorinated biphenyls (Stendell and others, 1988). Eggs contained 0.03 part per million of mercury. These contaminant levels were thought to be too low to have detrimental effects on the birds, and no contaminants were related to eggshell thinning.

Ferruginous Hawks will sometimes scavenge black-tailed prairie dogs, Richardson's ground squirrels, and other animals shot for recreation or pest control (Chesser, 1979; Knopper and others, 2006; Pauli and Buskirk, 2007). Lead bullet fragments can remain in the carcasses and can be ingested by scavenging raptors, exposing the birds to lead poisoning (Knopper and others, 2006; Pauli and Buskirk, 2007). Poisoned colonies

of prairie dogs may attract Ferruginous Hawks because of the ease of scavenging dead prairie dogs (Vyas and others, 2017). In Colorado, two prairie dog colonies were subjected to rodenticide poisoning. Vyas and others (2017) compared the foraging preferences of Ferruginous Hawks on the poisoned colonies compared to an adjacent, unpoisoned colony. Prior to the poisoning event, hawks foraged equally within all colonies. After the poisoning, hawks hunted only in the treated colonies, exposing them to the risk of secondary poisoning.

Ferruginous Hawks may be fairly resilient to the presence of roads but less resilient to the presence of energy development. In North Dakota, nests within 0.5 km of an interstate highway or other well-traveled road had similar nest success (at least one young was fledged) as other nesting pairs (Gilmer and Stewart, 1983). In moderately undisturbed shrubsteppe in Idaho, nesting pairs had more primary and secondary roads near their nests than did random points (Hansen, 1994). From a sample of 39 nests, the mean distance from a nest to buildings was 9 km, to primary roads was 5.6 km, and to secondary roads was 0.4 km. The mean length of road within 3 km of nests was 12.6 km. Ferruginous Hawks may become habituated to vehicular disturbance; in grasslands of Alberta and Saskatchewan, Nordell and others (2017) reported that the probability that an adult Ferruginous Hawk flushed from a nest varied with type of approach by investigators, the amount of vehicular traffic, nest substrate, and the number of previous visits. The probability that a Ferruginous Hawk flushed was five times greater when an observer exited a vehicle than when a vehicle approached on a highway (considered a high-traffic volume road at 100 to 415 vehicles per day), an approach on foot had a probability nearly four times greater than a highway approach, and a vehicular approach on range roads (that is, a paved or gravel road around townships with low- to moderate-traffic volume of 21 to 46 vehicles per day) had about equal probability as highway approaches. Hawks nesting in artificial platforms were twice as likely to flush as tree-nesting hawks. Probability of flight increased by about 18 percent with each subsequent visit to a nest by an investigator (Nordell and others, 2017). Likewise, Keeley and Bechard (2011) reported increased nest defense with consecutive human visits to nesting Ferruginous Hawks in New Mexico. Hawks in a rural environment flushed when an investigator was an average of 486 m from the nest, compared to 340 m for hawks in an exurban area. To prevent 95 percent of nest-attending hawks from flushing, an investigator needed to stay 648 m from nests in a rural environment and 480 m in an exurban environment.

Ferruginous Hawks are susceptible to electrocution and injuries from collisions with power lines (Harmata and others, 2001) and are at risk for collisions with wind turbines (Smallwood and others, 2008; Smallwood and Thelander, 2008). Beston and others (2016) identified the Ferruginous Hawk as a species most likely to experience population declines from wind facilities, based on a prioritization system that included metrics of turbine risk. Wulff and others (2016) examined diurnal flight heights of Ferruginous Hawks and determined that the species' mean flight height was 60.7 m, which is within the rotor-swept zone of wind-turbine blades. In Oregon, nest success for Ferruginous Hawks decreased as the number of wind turbines within a 32-km^2 home-range buffer increased (Kolar and Bechard, 2016). The estimated probability of surviving the median post-fledging period within 2.4 km of wind turbines ranged from 85 percent with no wind turbines to 49 percent with a density of 20 wind turbines. No fatalities for radio-marked fledglings were attributed to wind turbines, but juveniles that hatched from nests in areas of greater turbine density were more likely to die from predation or starving after fledging and prior to becoming independent compared to juveniles in areas of lower turbine density.

In western North Dakota, density of nesting pairs and fledging success did not differ between areas of high intensity oil and gas extraction (for example, 1,273 new wells over a 3-year period) compared to low-intensity areas (for example, 18 new wells) (Wiggins and others, 2017). However, between-year re-use of nest sites was lower in the high-intensity area than in the low-intensity area and lower than in other parts of the species' range. In northern Montana, petroleum development in breeding areas appeared to have no negative impacts on the productivity of Ferruginous Hawks (Zelenak and Rotella, 1997). In north-central Montana, the number of fledglings produced per nest in areas disturbed by oil-field activities compared to undisturbed areas did not differ, and no mortalities were directly attributed to oil-field activities (Van Horn, 1993). In Wyoming, the distance to active oil and gas well pads, the number of active oil and gas well pads, and the length of improved roads did not affect daily nest survival rate or fledgling production (Wallace and others, 2016). In Idaho, the nesting patterns of raptor species have changed as a result of the alteration and fragmentation of shrubsteppe landscapes by energy development (Coates and others, 2014). Common Ravens (*Corvus corax*) and Red-tailed Hawks (*Buteo jamaicensis*) have displaced Ferruginous Hawks; ravens, in particular, have exploited anthropogenic structures such as electrical transmission towers as a nesting substrate, boosting their numbers and competitiveness over Ferruginous Hawks. Furthermore, Common Ravens and Red-tailed Hawks were more likely to nest in fragmented shrubsteppe areas (that is, areas that were near agriculture or close to habitat edges) than Ferruginous Hawks, which preferred more-contiguous sagebrush cover distant from vegetation, roads, and energy facilities (Coates and others, 2014). In Utah's Uintah Basin, Ferruginous Hawks selected nest sites in an area undergoing rapid oil and gas development (Keough and Conover, 2012), possibly owing to greater prey abundance near wells.

In Colorado, Ferruginous Hawks as well as Golden Eagles (*Aquila chrysaetos*) and Swainson's Hawks (*Buteo swainsoni*) showed significant changes in their home ranges as a result of military activity (Andersen and others, 1990). Birds that had been exposed to military activity showed greater shifts of home-range centers, greater July-to-August increases in home-range sizes, and more frequent and greater movements outside of their territories compared to birds that had not been exposed.

Management Recommendations from the Literature

Ferruginous Hawks have declined in many rural areas where loss of nesting and foraging habitats to human development has been extensive, and effective conservation and management efforts to protect these habitats will require a focus on protecting large areas of grassland with low shrub cover (Wallace and others, 2016), as well as the collaboration of private landowners and public agencies (Olendorff, 1993). The protection of large tracts of native prairie from conversion to monotypic stands of grass or other types of agriculture has been recommended by Howard and Wolfe (1976), Lardy (1980), Janes (1985), Schmutz (1991a), and Ng and others (2017). Coates and others (2014) recommended protecting large tracts of native sagebrush communities from anthropogenic disturbances such as energy development. The protection of natural nesting substrates in altered sagebrush habitats is especially important because fragmented areas favor nesting Common Ravens over Ferruginous Hawks (Coates and others, 2014). Coates and others (2014) also suggested that when changes to and loss of the natural sagebrush community from anthropogenic alterations become high enough, Red-tailed Hawks and Ferruginous Hawks may begin to nest on artificial structures such as transmission lines, signaling the deterioration of natural habitat and the need for mitigating measures. The protection of aspen stands in bunchgrass prairie will provide natural nesting substrates for Ferruginous Hawks, whereas the spread of conifers and large shrubs will give Red-tailed Hawks and Swainson's Hawks a competitive advantage over Ferruginous Hawks (Kennedy and others, 2014).

Ferruginous Hawk populations will benefit from the protection, enhancement, or creation of nesting substrates, through such means as fencing of nest trees that are at risk of livestock damage, supporting heavy tree nests that are at risk of toppling, and building artificial nesting structures where nest sites are otherwise lacking (Olendorff, 1973; Smith and Murphy, 1978; Houston, 1985; Leary and others, 1998; Kennedy and others, 2014). Other successful nest-structure management techniques are removing some of the previous year's nesting material to reduce the chance of toppling, realigning the nest over a vertical axis, widening the base of the nest, reinforcing the base of the nest using wire netting or other materials, moving the nest to a safer location, or providing protection from predators by nailing tin sheathing around tree bases (Craig and Anderson, 1979). In converting tree communities to grasslands, nest sites can be provided or maintained by leaving individual trees, scattered stands of trees, or scattered individual trees (Olendorff, 1993). Artificial nest platforms are an effective tool for improving breeding success where loss of natural nest substrates has occurred (Wallace and others, 2016; Ng and others, 2017; Wiggins and others, 2017). Platforms on utility towers may be used to benefit nesting Ferruginous Hawks, but it is important to place platforms in areas where fecal material will not contaminate lines (that is, not directly above lines or insulators) (Steenhof and others, 1993).

Because Ferruginous Hawks are easily disturbed during the breeding season and prone to nest abandonment, nest sites should not be disturbed from March 1 to August 1 (Olendorff 1993). Lardy (1980) recommended the closure of public-use areas near nest sites during the breeding season, whereas Olendorff (1993) recommended the closure of public land to firearm activities where dense populations of Ferruginous Hawks are particularly susceptible to shooting. When possible, Olendorff (1993) recommended applying treatments (for example, chaining, disking, plowing, or burning) during the nonnesting season to avoid direct impacts to nesting Ferruginous Hawks, their nests, and their prey during the nesting season. Although rest-rotation and deferred-rotation grazing systems have been encouraged (Olendorff, 1993), delaying grazing until after the completion of incubation has been recommended (Atkinson, 1992).

To minimize disturbance of nesting areas, Atkinson (1992) recommended providing information about nest locations to ranchers, seismic crews, prospectors, and others working in nesting areas. The establishment of buffer zones around nest sites might prevent nest abandonment (Leslie, 1992). White and Thurow (1985) recommended creating a disturbance-free buffer zone of 0.25 km around nest sites, whereas Olendorff (1993) suggested buffer zones of 0.25 km for brief disturbances, 0.5 km for intermittent activities, 0.8 km for prolonged activities, and at least 1 km for construction or similar activities. Atkinson (1992) suggested that a minimum distance of 0.45 km be maintained from the nest, Nordell and others (2017) suggested 0.50 km for low-impact disturbances, and Keeley and Bechard (2011) recommended a buffer distance no shorter than 0.65 m.

Prey habitat can be improved by protecting areas with abundant ground squirrels (Wallace and others, 2016) and prairie dog colonies, including areas considered for exurban housing development (Keeley and others, 2016); enlarging grassland areas to allow for the expansion of ground squirrels (Houston and Bechard, 1984); protecting native shrub vegetation; and increasing edge habitats (Howard and Wolfe, 1976; Ng and others, 2017). If chaining is used to control brush, subsequent windrowing of the brush provides cover for prey (Olendorff, 1993). When converting land from sagebrush steppe to grassland, Ferruginous Hawks will benefit from the creation of a mosaic of treated (chained or disked) and untreated areas (Howard and Wolfe, 1976). Maintaining or restoring sagebrush/grass rangeland and removing pinyon pine (*Pinus edulis*)/Utah juniper stands will attract small rodents for foraging Ferruginous Hawks (Howard and Wolfe, 1976). If it is necessary to control prey, lowering the peaks of cyclic highs of lagomorph or rodent populations may benefit Ferruginous Hawks more than completely exterminating these prey species (Olendorff, 1993). In regions where prairie dogs or ground squirrels are shot for recreation or pest control, using

nontoxic bullets and collecting and disposing of carcasses can reduce the threat of lead poisoning to scavenging Ferruginous Hawks (Knopper and others, 2006; Pauli and Buskirk, 2007). Where rodenticide is applied to prairie dog colonies, removal of carcasses will reduce the chance of secondary poisoning to foraging Ferruginous Hawks (Vyas and others, 2017).

To prevent collisions of Ferruginous Hawks with wind turbines, Wulff and others (2016) and Kolar and Bechard (2016) recommended avoiding wind-turbine placement in locations with high concentrations of trees or shrubs that provide nesting and perching habitat and avoiding placement in locations with high prey densities, such as prairie dog towns, in which hawks concentrate their foraging activities. Kolar and Bechard (2016) cautioned that a high density of wind turbines near Ferruginous Hawk nesting habitat could lower reproductive success. In areas where energy development has significantly altered the landscape, several authors have recommended mitigation measures, including erecting artificial nest structures to provide alternative nesting sites and minimizing energy-related disturbances until 45 days after young have fledged (Konrad and Gilmer, 1986; Ng and others 2017; Wiggins and others, 2017).

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