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REPRODUCTION OF FERRUGINOUS HAWKS EXPOSED TO CONTROLLED DISTURBANCE

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ABSTRACT.—The Ferruginous Hawk (*Buteo regalis*) is a conspicuous grassland bird that is sensitive to human disturbance. In 1978 and 1979, we studied 62 nesting pairs and recorded their behavior and nesting success. At 24 of these nests, we daily created disturbances designed to simulate those associated with land development on western rangelands. The other nests were not disturbed. Treated nests and control nests differed significantly ($P < 0.05$) in the number that successfully fledged young. Thirty-three percent of the disturbed nests were deserted by the adults, although our presence in the vicinity of the nest was brief. Those disturbed nests that were successful fledged significantly fewer young ($P < 0.05$) than undisturbed nests. Based on our cumulative data, adults did not flush 60% of the time if our activities were more than 120 m from the nest and 90% of the time if they were more than 250 m from it. Accordingly, for intermittent and brief human disturbance during years when prey are abundant and Ferruginous Hawks are in good physiological condition, we suggest that a minimum buffer zone of 0.25 km around the nest is sufficient to prevent nest desertion by at least 90% of the population. Buffer zone should be expanded in years when prey are scarce, i.e., when the hawks appear to be less tolerant of disturbance.

The Ferruginous Hawk (*Buteo regalis*) is seriously affected in some areas by land development and, consequently some populations of the species are apparently small and may be declining. Reflecting this trend, the species has been on the Audubon Blue List since the list was established in 1971 (Tate and Tate 1982). A minimum number of breeding pairs was recently estimated at 2,810–3,590 over the entire range (M. Call, unpubl., U.S. Bureau of Land Management, Denver, CO, 1980). Ferruginous Hawks are particularly sensitive to human activity (Olendorff and Stoddard 1974, Fyfe and Olendorff 1976, Woffinden and Murphy 1977) and are prone to desert their nests if disturbed during incubation. Nonetheless, the species can respond well to management (White 1974, Porter and White 1976, Murphy 1978) so that it may be possible to adjust human activities to minimize ecological disturbance to it. Kennedy (1980) suggested such an approach in her assessment of conflicts concerning raptors and land use.

It is becoming increasingly difficult to maintain critical wildlife habitat as the multiple-use demands on land intensify. The amount of disturbance that sensitive species will tolerate must be measured so that land management plans can be devised that are compatible with the species' needs. Our objectives were to determine how Ferruginous Hawks respond to disturbances, the levels of disturbances they will tolerate, and the size of buffer zones needed by disturbed pairs to maintain a level of nesting success and productivity similar to those of undisturbed pairs. To accomplish this, we considered the natural tolerance thresholds of the species, the relationship of tolerance to prey availability, and the nesting history of the population as related to disturbance.

Most previous buffer zone recommendations from management agencies and the scientific community have been based primarily on best guess or anecdotal knowledge. Estimates of the sensitivity of Ferruginous Hawks, or raptors in general, to human disturbance were mainly obtained from observations made during studies of their breeding ecology. A significant exception is the Bald Eagle (*Haliaeetus leucocephalus*) for which considerable data were collected to aid development of sound management policies (cf. Grier 1969, Gerrard and Gerrard 1975, Mathison et al. 1977). Stalmaster and Newman (1978) examined the effects of some controlled disturbances on nonnesting Bald Eagles, but few other attempts have been made to identify, quantify, and control variables that cause nest desertion.

METHODS AND STUDY AREA

We conducted our study throughout the Raft River Valley (42°N, 113°W), Cassia County, south-central Idaho (Fig. 1). The northern boundary of the valley opens onto the Snake

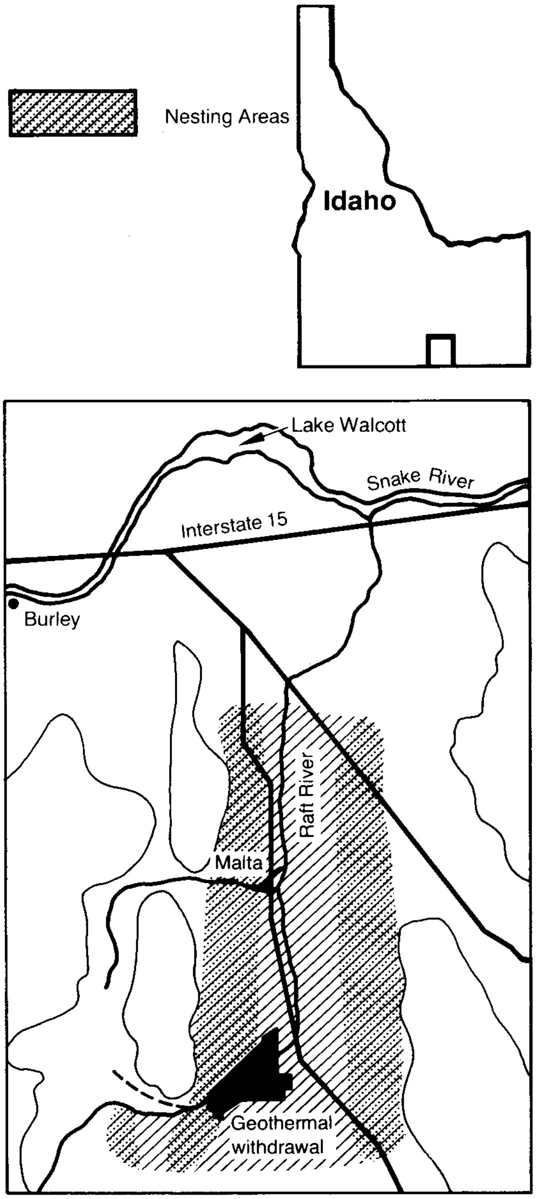

FIGURE 1. Study site (hatched) and primary or high density (stippled) nesting area of Ferruginous Hawks in Raft River Valley, Idaho. The vertical length of the hatched area is about 50 km.

River Plain; the south, west, and east sides are bordered by mountains. The study area is about 988 km^2 at an elevation of about 1,500 m. We chose this site because the valley has a large population of Ferruginous Hawks whose history had been monitored continuously since 1972 (Powers et al. 1973, Howard 1975, Thurow et al. 1980). Initially, we also chose this site because it had a high potential for increased human use, since the U.S. Department of Energy Geothermal Test Facility planned to develop the geothermal resources of the valley. The facility has been closed, however, and further rapid change in the valley seems unlikely.

The region's physiography and climate are typical of Great Basin cold deserts (Odum 1971). Vegetation is characteristic of the northern desert shrub biome as delineated by Cronquist et al. (1972). Big sagebrush (*Artemisia tridentata*) is the dominant shrub throughout the valley, but greasewood (*Sarcobatus vermiculatus*) and shadscale (*Atriplex confertiofolia*) are dominant on saline soils on the valley floor. Other major plants include rubber rabbitbrush (*Chrysothamnus nauseosus*) and black sagebrush (*Artemisia nova*). Utah juniper (*Juniperus osteosperma*) and piñon pine (*Pinus edulis*) are generally limited by lack of moisture to elevations above 1,500 m. Ground vegetation consists of a variety of forbs and grasses, including squirreltail grass (*Sitanion hystix*), crested wheatgrass (*Agropyron spicatum*), and tansy mustard (*Descurainia richardsonii*). The little agricultural and rangeland development that has occurred in the study area is limited primarily to production of alfalfa on the valley's floor. Bench areas that were cultivated early in the century (F. Gunnell, pers. comm.) have reverted to original vegetation since being abandoned after droughts in the 1920s and 1930s.

CENSUSING METHODS

Territories of Ferruginous Hawks in Raft River Valley were first identified by Powers et al. (1973). Many were surveyed annually by Howard (pers. comm.) between 1972 and 1977. We began our study in 1978. We censused the area by vehicle from existing ranch roads between April and July in both 1978 and 1979. Nests were most often located by traveling along the sagebrush-juniper ecotone searching for flat-topped juniper trees that are typical nest sites of Ferruginous Hawks (cf. Thurow and White 1983). We found ground nests by observing the behavior of pairs in areas that lacked trees suitable for nest sites; these nests were typically near utility poles that provided a perch. We also conducted a survey by airplane in late May 1979, when young were large and downy white and thus easily seen from the air. During these census periods, we did not approach the nests, but examined them from as far away as possible using a telescope to determine if they were active.

METHODS OF DISTURBING NESTING HAWKS

In early May 1978, we began disturbing randomly selected nests in four ways: we (a) approached them on foot (three nests), (b) approached them in a vehicle (three nests), (c) continuously operated a 3½-hp gasoline engine near the nest (two nests), or (d) fired a 0.22-

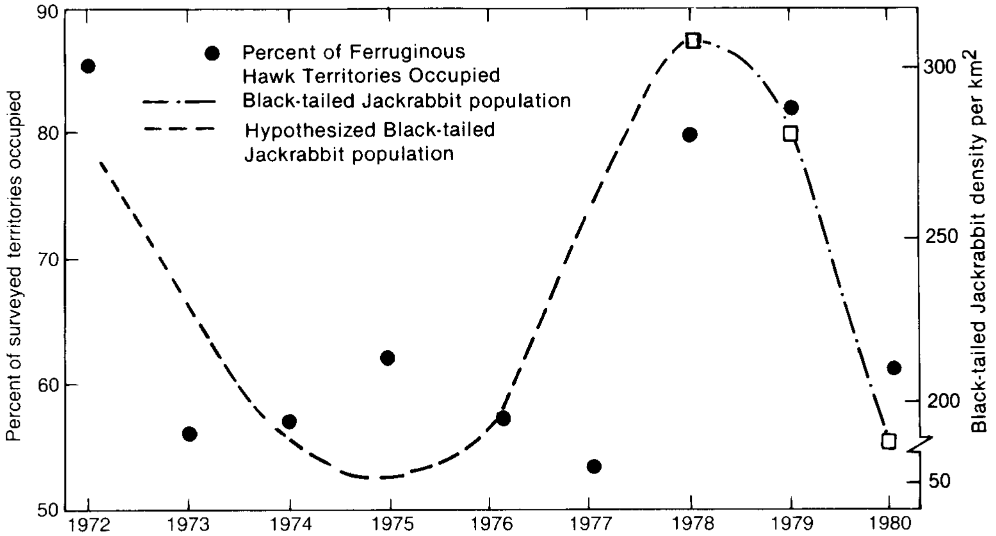

FIGURE 2. Percent of territories occupied by Ferruginous Hawks generally coincided with the jackrabbit population cycle between 1972 and 1980. The 1972–1977 hawk data are from Powers et al. (1973), Howard (1975), and Howard (field notes and pers. comm.). The 1972–1977 rabbit data are estimations and extrapolations from observations by Howard, C. Trost, and L. Stoddart (pers. comm.), and Gross et al. (1974). Open squares represent rabbit transect data taken during this study and in 1980.

caliber rifle about every 20 m as we approached the nest, beginning approximately 500 m away and continuing until the adult flushed (three nests). Treatment (d) was meant to simulate periodic noise associated with human activity.

We stopped using firearms in 1979 because we could not separate the effect of the noise from the presence of researchers. In other respects, however, we created disturbances at randomly selected nests as we had in 1978: (a) five nests were approached on foot, (b) five nests by vehicle, and (c) four nests were exposed to sounds produced with wind- or battery-powered noisemaking devices (Sonalert® Beeper) placed 30–50 m from nests. Noise levels from these devices at nest sites (about 80 dB) were designed to simulate sounds commonly produced at geothermal (or other type of development) sites. Some, but not all, of the pairs that we disturbed in 1978 were probably disturbed in 1979, as some of the same nests were used. They were not necessarily exposed to the same type of disturbance in both years.

We approached nests only to the point at which the attending adult flushed (physically left the nest), and then left the area immediately. Flushing distance was estimated and recorded as an indicator of the level of stress or anxiety beyond which the hawks could no longer tolerate the presence of the disturbing factor. Note, however, that this is probably not the distance at which stress is first induced, since stress levels of incubating birds probably rise long before they flush.

All of these nests were attended by incubating adults when we began disturbing them and they were disturbed once almost every day until the young either were ready to leave the nest (fledge) or were deserted. The time of day when nests were visited was variable, except that we did not disturb incubating birds immediately before or during inclement weather or near dusk. Data collected during each visit included presence or absence of adults, flushing distance, and general behavior of the adults. Control nests, once identified, were not revisited until mid-June. At this time, they and the disturbed nests were visited to determine the number of nestlings present. The average age of nestlings at this time was 3–4 weeks. In no case did this brief visit result in nest desertion.

PREY ASSESSMENT

Because the population dynamics and behavior of Ferruginous Hawks are closely related to the birds' food supply (Howard and Wolfe 1976; Smith et al. 1981; Figures 2 and 3), we attempted to estimate the density of lagomorphs (*Lepus* and *Sylvilagus*). We made morning walks along ten 1.6-km transects through habitats representing the vegetation in the valley. Each transect was chosen randomly and was censused once each year, in early July, when young Ferruginous Hawks typically fledge. To determine the rabbits' density from the transect data, we used the flushing distance equation of Hayne (1949) and the correction factor and censusing criteria of Gross et al. (1974).

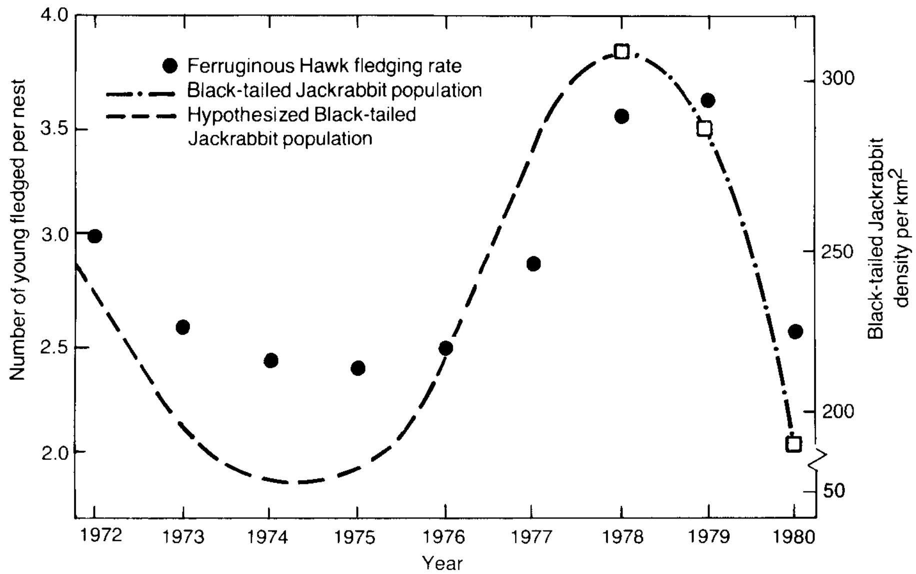

FIGURE 3. The fledgling rate of Ferruginous Hawks compared to the jackrabbit cycle over a 9-year period. See Figure 2 for sources of data concerning rabbits and hawks between 1972 and 1977. Open squares represent rabbit transect data taken during this study and in 1980.

RESULTS

CRITICAL VARIABLES IN THE NESTING BIOLOGY OF FERRUGINOUS HAWKS

Nesting territories of some raptors remain remarkably stable from year to year (Newton 1979). Furthermore, several species seldom build new nests, but repeatedly repair and reuse old ones. Observations of this population since 1972 by Howard (pers. comm.) show that these birds reuse their nests. Most of their territories contain alternate nest sites. Although the actual site used may change annually, the limits of the territory remain essentially constant. Consequently, we had no difficulty determining which nesting territories in the valley were active. Of the 107 nest structures of Ferruginous Hawks located in our study area, six were on the ground or a rocky outcrop; one was on a power pole; and the remainder were in juniper trees (cf. Woffinden and Murphy 1983).

Nest placement with regard to human dwellings or roads did not deviate from random. When the locations of these nests were compared to 100 random points with a paired t-test, there was no significant difference ($P < 0.05$). Nonetheless, since no nests were adjacent to homes, there was clearly some selectivity in nest placement and some minimum distance that the hawks maintained away from areas of human activity.

DISTURBED NESTS

The hawks differed slightly in response to our treatments but none increased their tolerance over time (Tables 1 and 2). In fact, most became sensitized to our disturbances, flushing at increasing distances until just before their eggs hatched (Fig. 4). Desertions occurred as late as 19 days after we began to disturb nests. The stages of development of the embryos in eggs from these deserted nests ranged from none (eggs freshly laid) to stages characteristic of

TABLE 1. Results of disturbances, by treatment method, for nests disturbed in 1978.

Method of disturbing nest	Number of visits to nests	Flushing distance (m)[a]	Results
Walk	18	31 (15–140)	Fledged 0 nestlings (3 young taken by predators—adults inattentive)
Walk	8	110 (25–180)	Nest deserted
Walk	6	53 (35–90)	Nest deserted
Motor	8	65 (35–200)	Fledged 4 nestlings
Motor	8	101 (40–320)	Fledged 4 nestlings
Walk (gunshot)	18	71 (25–320)	Fledged 2 nestlings
Walk (gunshot)	22	96 (5–275)	Fledged 2 nestlings
Walk (gunshot)	19	74 (5–320)	Fledged 4 nestlings
Drive	7	217 (20–480)	Nest deserted
Drive	6	221 (140–370)	Nest destroyed by wind
Drive	25	62 (20–500)	Fledged 1 nestling

[a] Based on visits during which adults flushed when we were less than 500 m from the nest. Values are means (ranges).

TABLE 2. Results of disturbances, by treatment method, for nests disturbed in 1979.

Method of disturbing nests	Number of visits to nests[a]	Flushing distance (m)[b]	Results
Walk	19 (5)	138 (20–400)	Fledged 3 nestlings
Walk	21 (7)	66 (20–150)	Fledged 2 nestlings
Walk	19 (2)	164 (70–300)	Nest deserted
Walk	26 (10)	196 (10–350)	Fledged 3 nestlings
Walk	24 (3)	118 (25–255)	Fledged 3 nestlings
Drive	24 (3)	90 (15–270)	Fledged 3 nestlings
Drive	8 (3)	127 (35–330)	Nest deserted
Drive	28 (1)	162 (35–400)	Fledged 3 nestlings
Drive	28 (1)	54 (15–180)	Fledged 2 nestlings
Drive	6 (3)	153 (20–400)	Nest deserted
Noise	NA[c]		Nest deserted
Noise	NA		Fledged 2 nestlings
Noise	NA		Fledged 3 nestlings
Noise	NA		Nest deserted

[a] Numbers in parentheses are visits when adults flushed at distances greater than 500 m or were absent.
[b] Based on visits during which adults flushed when we were less than 500 m from the nest. Values are means (ranges).
[c] NA = not applicable; we did not visit nests subjected to noise until after the eggs hatched.

embryos 3–4 days before hatching. In our experience, a female hawk usually will not desert after an egg begins to hatch or when there are nestlings in the nest. (These findings resemble those of Safina and Burger [1983] for many colonial waterbirds). Initial flushing distances in 1979 (Table 2) were higher than those in 1978 (Table 1) probably because four of the 14 nests that we disturbed in 1979 had also been disturbed in 1978. We presume that they were occupied by the same pairs both years and that the birds were already sensitized to disturbance from their previous experiences. We found no statistically significant correlation between numbers of eggs in nests and the birds' tendency to desert.

Of the four territories that failed to fledge young in 1978, none were used in 1979 (but three were used again in 1980). Of the five territories deserted in 1979, four were not used in 1980. In other words, eight of the nine disturbed nests that failed as a result of our disturbances were not used the following year, a significant reduction ($\chi^2 = 92.7$, 1 df, $P < 0.005$) considering that 93% of established territories are normally reoccupied each year (see below). We emphasize that when a pair deserted a territory, the birds did not simply move to an adjacent site the following year. Most of the traditional territories were occupied each year by other pairs. Therefore, if the pair from the deserted territory bred in the year following desertion, they would have had to move completely out of the area. The chance of this occurring with the consistency that the data indicate is unlikely.

None of the disturbance treatments produced significantly different effects on the birds,

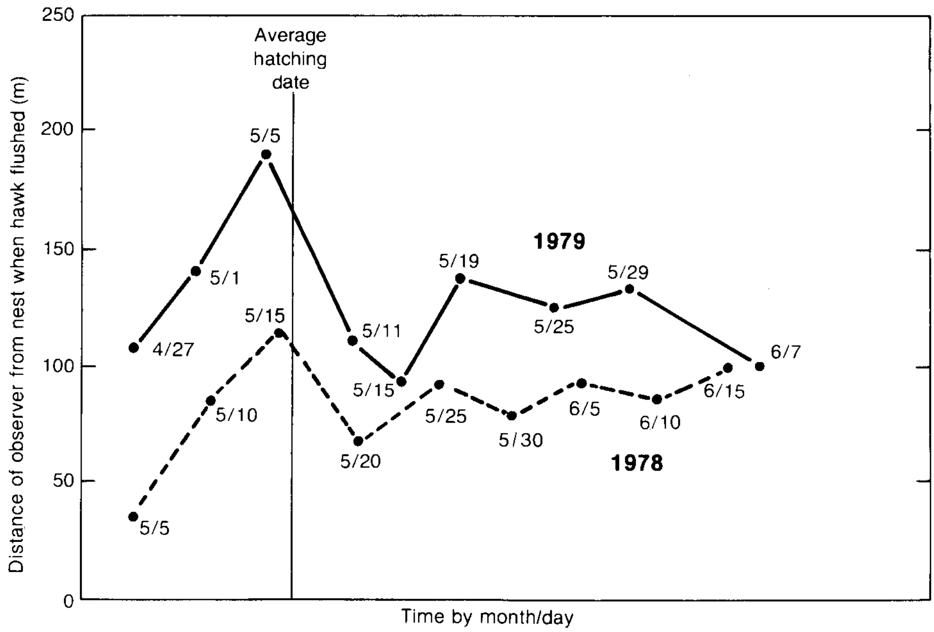

FIGURE 4. Mean flushing distances of Ferruginous Hawks during the nesting cycle. Values are 5-day averages. Ratios beside each closed circle are month/day of month.

TABLE 3. Fledging rates of Ferruginous Hawks in 1978 and 1979.

	Number of nests		Fledging rate (young/nest)	
	1978	1979	1978	1979
All disturbed nests	10	14	1.70	1.71
Successful disturbed nests	7	9	2.43	2.67
Control nests	17	21	3.53	3.81

TABLE 4. Distribution of the number of young fledged per nest.

Number of young fledged	Number of nests that fledged this many young			
	1978		1979	
	Control nests	Disturbed nests	Control nests	Disturbed nests
0	0 (0)[a]	4 (40)	0 (0)	5 (36)
1	0 (0)	1 (10)	1 (5)	0 (0)
2	3 (18)	2 (20)	1 (5)	3 (21)
3	4 (23)	0 (0)	4 (19)	6 (43)
4	8 (47)	3 (30)	10 (48)	0 (0)
5	2 (12)	0 (0)	5 (24)	0 (0)

[a] Numbers in parentheses are the percentages of nests in each category.

but their effects were significantly different from those of the control treatment (Duncan's multiple range test). Therefore, we combined the forms of disturbance for purposes of analyzing differences between disturbed and control nests. Only 52% of territories containing disturbed nests ($n = 24$) were occupied the year after disturbance. Excluding desertions, 75% of them were used the next year. In contrast, 93% of the territories containing control nests ($n = 38$) in 1978 were occupied in 1979. This difference in use of territories containing disturbed nests (excluding desertions) and those containing control nests is not significant.

SUCCESS OF DISTURBED NESTS

Of the 10 active nests disturbed in 1978, seven were successful, fledging 17 young for a fledging rate of 2.43 young/successful nest. However, if the three disturbed nests that were deserted that year are included, the fledging rate was only 1.70 young/nest, which was significantly higher than that of successful disturbed nests ($P < 0.05$). Of greater biological significance is the fact that control nests fledged, on average, one young more than successful nests that we disturbed or twice as many young if all disturbed nests are considered (Table 3). None of the disturbed nests in either year of the study fledged five young and only 30% of them fledged four young (Table 4). By comparison, 59% of the control nests in 1978 and 72% in 1979 fledged four or five young. Many disturbed nests fledged fewer young than control nests. For example, only one control nest fledged fewer than two young during our study, but 10 disturbed nests did so.

During 1979, nine of the 14 disturbed nests were successful and fledged 24 young for a fledging rate of 2.67 young/successful nest, or 1.71 young/nest for all disturbed nests (successful and unsuccessful), whereas 3.81 young fledged on average from control nests (Table 3). The difference of 1.16 young/nesting attempt between successful disturbed and control nests is statistically significant ($P < 0.05$).

In the Raft River Valley, about 91% of the biomass in the diet of Ferruginous Hawks consisted of lagomorphs, principally jackrabbits (Thurow et al. 1980). The density of Black-tailed Jackrabbits (*Lepus californicus*) was estimated to be 309/km^2 in 1978 and 287/km^2 in 1979. These densities are high compared with population estimates from neighboring Curlew Valley taken during low points in the jackrabbit cycle (Gross et al. 1974), suggesting that the prey population was at or near peak density during the study period.

DISCUSSION

LIMITATIONS OF THE STUDY DESIGN

Many factors may have affected the results we obtained. Among the variables that were not controlled, and in some cases not measured, were: (1) clutch size, (2) disturbances not caused by researchers, (3) our inability to fully measure stress or anxiety in hawks, (4) stress induced by inclement weather, (5) stage of incubation when disturbance began, (6) presence or absence of a mate when the nest was approached, (7) different responses of individual hawks to disturbance, (8) health of individual hawks, and (9) previous exposure of these individuals to human disturbance.

The response of Ferruginous Hawks to various types of human activity appears to vary considerably among individuals (Tables 1 and 2). Nevertheless, a population norm does exist. The intensity of the response depends largely on whether the form of disturbance is familiar or not (cf. Gilmer and Stewart 1983, for example). Hawks may tolerate considerable noise close to their nests if they are familiar with it, especially if humans are not visible or otherwise obviously associated with it. For example, military jets that occasionally flew low over the study area during training exercises did not appear to bother the hawks. We suggest that Ferruginous Hawks did not consider such aircraft as a potential danger, particularly since the noise from them did not reach the nest until the planes had already passed over a nest and were 2–3 km away. Similarly, hawks were not alarmed when, during our attempt to find nests, we flew within 30 m of their nests in a Cessna 185. In one case, the female continued to feed her young without interruption.

Unlike previous reports of substantial nest desertion by raptors as a result of human activity (cf. Fyfe and Olendorff 1976), the number of disturbed nests that were deserted in our study (40% in 1978 and 36% in 1979) was unexpectedly low. Several factors may have been responsible for this relatively moderate desertion rate. During the disturbances, we approached nests only to the point at which the attending adult flushed and then left the area immediately. This contrasts with many studies of the breeding biology of raptors since we never actually climbed the nest trees to determine clutch size or to collect other data until the young could be banded, about 25 days after hatching. We suspect that more desertions would have occurred had we climbed to the nests during incubation.

New forms of disturbance may cause desertion if sustained, even though humans are not directly associated with them. For example, we concealed an electronic noisemaker 15 m away from a nest in 1979 while the female was absent. (The noise level produced at 15 m from the nest was about 100 dB-B weighted). When the female returned, she landed on the edge of the nest, but appeared startled and quickly left. She approached the nest once more 10 min later, but did not land on it. Later in the day, she made two more passes at the nest only to veer away when about 6–7 m from it. She had apparently been so startled by the noise when she first heard it that she became immediately sensitized to it and abandoned the nest (she did not return the following day). She could not see the noise maker because it was small and concealed.

We hypothesize that the unfamiliar nature of the noise caused the hawk to desert the nest since on other occasions it was clear that hawks could tolerate substantial disturbance. Apparently, if a disturbance like that created by a cow rubbing against the nest tree or a tractor plowing a nearby field are periodic and ongoing when adults first arrive at their nests and are not perceived as threatening, hawks habituate to them. For example, we know of several pairs of the Peregrine Falcons (*Falco peregrinus*) and Golden Eagles (*Aquila chrysaetos*) that occupied and successfully raised young at new nest sites only a few hundred meters from areas of high disturbance (e.g., at blasting, construction, quarrying, and mining sites, and at airports).

Another factor that may have influenced the desertion rate in our study was the availability of jackrabbits (cf. Smith et al. 1981) and thus the nutritional condition of the hawks. In 1978 and 1979, populations of black-tailed jackrabbits in Raft River Valley were at peak density, according to their approximately 10-year population cycle (Wagner and Stoddart 1972) and extrapolations from data collected nearby in Curlew Valley (Gross et al. 1974; L. C. Stoddart, pers. comm.). Hence, breeding adult hawks could easily obtain food for themselves and their young, and appeared to be in good physical condition. In 1980, however, the jackrabbit population had declined dramatically (Fig. 2) owing to an epizootic outbreak. We disturbed three nests while eggs were present that year. Each was deserted soon thereafter. This disturbance occurred when we attempted to put an egg containing a transmitter into the nest in order to determine the incubating hawks' heart rate and thus obtain a more accurate measurement of stress. These instances of desertion contrast sharply with what happened at several nests (not part of this study sample) that we inspected in 1978 and 1979: none was subsequently deserted. Furthermore, in 1978 and 1979 we took fertile eggs from deserted nests that we had disturbed and put them in nests that were not part of the study in an attempt to save the embryos. None of these actions caused desertion. This suggested to us that the apparent sensitivity of Ferruginous Hawks to disturbance in 1980 was due to lower prey abundance (jackrabbit populations estimated at 169/km^2 based on transect data; compare with data for 1978–1979), which probably affected their physiological state adversely.

Disturbed nests rarely fledged four or five young, but commonly fledged one or none (Table 4). The reverse pattern was true for control nests. Behavioral data collected during each nest visit suggested that adults became sensitized to our presence and were less than normally attentive to their young, which probably reduced their fledging success. Numerous observations supported this conclusion. For example, parents at disturbed nests often remained away from the nest site for unusually long periods once the young had hatched; however, parents at control nests were often in attendance for the first several weeks after hatching. Parents at disturbed nests also showed little defensive behavior (i.e., screams, stoops) and sometimes did not appear at the nest for up to 5 min after we arrived. By contrast, control pairs were much more aggressive and appeared quickly upon our arrival. Such neglect increases the vulnerability of nestlings to inclement weather and predation, as was clearly illustrated in one nest that we visited after a thunderstorm. The downy, 1-week-old young had not been brooded and one died (exhibiting pneumonia-like symptoms) several days later. In another case, 2-week-old nestlings were apparently killed by Common Ravens (*Corvus corax*) because of the parents' inattentiveness. Parental neglect at disturbed nests also increased the incidence of addled eggs and the death of smaller, weaker young in nests containing four or five young. Heat stress may have caused the death of these young since underfed young do not cope with stress as well as those that are well-fed (Tomback and Murphy 1981). In control nests, the smaller young survived.

The presence of humans near nests may also raise the mortality rate by causing young hawks to fledge prematurely. At one nest, for example, our presence caused a young hawk, only recently fledged, to make a taxing and lengthy premature flight. Within 20 min a coyote (*Canis latrans*) was scouting the area where the young bird had landed, perhaps having seen the young in its unstable flight. Greater public use of the nesting habitat of Ferruginous Hawks may increase the premature departure of inexperienced young birds from nests and thereby increase the importance of mortality factors such as predation.

Although nest placement with regard to human dwellings or roads did not deviate from random, none of the nests were adjacent to homes. Clearly, hawks exercise some selectivity in nest placement and stay some minimum distance away from areas of human activity. Nesting success of Ospreys (*Pandion haliaetus*) is reportedly better if they nest some distance from areas of human activity rather than near them (Swenson 1975; L. Richardson, unpubl., Yale School of Forestry and Environmental Studies, New Haven, CT, 1980).

BUFFER ZONE

Our study was designed to simulate the effects of low-level human activity on nesting Ferruginous Hawks. The birds were disturbed only once a day, and we left their territories as soon as they flushed from their nests. A critical factor in a disturbance is the duration the bird is kept off eggs. If the eggs are cool when a hawk returns to the nest, it is our experience that the bird is reluctant to resume incubating and likely to abandon the nest. Also, if eggs are exposed to high ambient temperatures for even brief periods of time, the proteins are quickly denatured (Bartholomew 1972). For example, the lethal internal egg temperature of the Herring Gull (*Larus argentatus*) was reached within 2 h on a sunny morning at an air temperature of 18°C (Drent 1972). Our study simulated brief disturbances after which the hawk was free to return almost immediately. Had our activity been continuous or of several hours duration, its impact would have been substantially greater.

Defining a "buffer zone," i.e., the minimum area around a nest that must be kept free of human intrusion to prevent harmful effects associated with disturbance, is an important decision tool for land managers or developers. We would prefer to see ecosystems kept intact (cf. Wagner 1977) rather than divided into isolated islands set aside for nesting raptors, because aspects of general land use other than restricted areas also affect the health of raptor populations. However, we also realize that a community approach is not always practical for many types of land use. Our observations suggest that a sufficient buffer zone for brief human disturbance around Ferruginous Hawk nests is 250 m. Adults will not flush 90% of the time if human activity is confined to distances greater than this. However, several factors must be considered when one defines the size of such a buffer zone. Our data, for example, were collected during years when food was abundant and consequently hawks were presumably in prime physiological condition and able to cope well with the induced stress. In years when prey are scarce, the buffer zone may need to be considerably larger. Other aspects of the nest site, such as the degree to which the nest is exposed or concealed, may also affect buffer distances best maintained around individual nests.

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