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PRODUCTIVITY OF GOLDEN EAGLES WEARING BACKPACK RADIOTRANSMITTERS

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ABSTRACT.—We examined the association between the presence of backpack radiotransmitters and Golden Eagle (*Aquila chrysaetos*) reproduction (percentage of occupied territories producing young, and number of nestlings produced) over three years. The association between radio-tagging and nesting success and the number of nestlings produced varied significantly among years. A negative association with tagging was observed in one of three years, which coincided with low prey (jackrabbit) populations and a cold spring. However, small sample size and breeding by subadults may confound this result.

KEY WORDS: Aquila chrysaetos; *Golden Eagle; productivity; radio-tagging; weather.*

La productividad de águilas (*Aquila chrysaetos*) con radio emisora

RESUMEN.— Nosotros examinamos la asociación entre la presencia de un radio ajustado en la espalda y la reproducción (porcentaje de territorio ocupado tenido jóvenes, y numeros de pajaritos producidos) de la águila (*Aquila chrysaetos*) por tres años. La asociación entre marcando con el radio y el desarrollo de nidos y los numeros de pajaritos producidos variado mucho entre clases de edad. Una asociación negativa con marcando fue observado uno de los tres años, que coincido con poblaciones bajas de presa y una primavera fría. Sin embargo, muestras pocas y reproducción mínima de subadultos puede confundir resultados.

[Traducción de Raúl De La Garza, Jr.]

Effects of radio-tagging on behavior should be considered before making inferences about an animal's biology (Wanless 1992, Hiraldo et al. 1994). Radio-tagging may have little effect (Vekasy et al. 1996), or may adversely affect condition and behavior by abrading skin, influencing time budgets, decreasing foraging efficiency, increasing metabolic costs or causing desertion of eggs or nestlings (Gessaman and Nagy 1988, Massey et al. 1988, Hooge 1991, Foster et al. 1992). Effects may vary year to year with weather and prey abundance (Peitz et al. 1993, Vekasy et al. 1996).

We examined reproductive responses of Golden Eagles (*Aquila chrysaetos*) wearing backpack radiotransmitters in the Snake River Birds of Prey National Conservation Area (NCA) from 1991–94. Our objective was to determine the influence of radio-tagging on reproduction and identify other factors that may have interacted with radio-tagging to either increase or decrease the magnitude of the effect.

METHODS

Throughout the course of this study 27 Golden Eagles were captured and 15 were radio-tagged (Table 1). Our sample during winter 1991–92 included eight eagles at seven nesting areas (sections of cliffs or powerlines where nests are found each year, but where no more than one pair has ever bred at one time). Both members of the pair were tagged at one site. In 1992–93 our sample increased by two nesting areas where we tagged the male of one pair and the female of the other pair. We also radio-tagged two additional birds in our original seven areas in 1992–93; a female after her mate's transmitter failed, and a male where we had previously trapped and radio-tagged the female. Our sample size was reduced by two nesting areas during winter 1993–94, when we found one female dead of unknown cause, and we failed to locate one male. Captured eagles were weighed and measured, and we determined sex using weight and footpad length and observations of copulation (Edwards and Kochert 1986).

Golden Eagle control nesting areas consisted of all oc-

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Table 1. Golden Eagle territories where birds were radio-tagged and productivity was studied during 1991–94 breeding seasons in the Snake River Birds of Prey National Conservation Area.

	Number of Eagles		Individuals Used in Analyses			Years Used in Analyses			
Territory	Captured	Instrumented	Sex	Age	Capture Date	1991	1992	1993	1994
A—Black Butte	2	1	M	Ad	12 Nov 91		—	—	—
B—Beercase	2	2	M	Ad	18 Jan 92		—	—	—
C—Wildhorse	2	2	F	Ad	14 Oct 91		—	—	—
			M	Ad	16 Dec 92			—	—
D—PP&L 119	5	4	M	Ad	19 Feb 91	—	—	—	
			F	Ad	23 Oct 92		—	—	—
			M	Subad	11 Mar 94				—
E—Pole 369	0[a]	0[a]	F	Subad	17 Dec 91			—	
F—Grand View	2	2	F	Subad	17 Dec 91	—			
			M	Ad	24 Oct 92		—	—	—
G—Ogden	1	1	M	Ad	14 Dec 92		—	—	—
H—Beecham	1	1	M	Ad	22 Nov 91	—	—	—	—
I—Cabin	12	2	F	Ad	06 Dec 91	—	—	—	—
			M	Ad	12 Apr 94				—
Total	27	15							

[a] Individual moved from Grand View Sand Cliff territory to Pole 369 territory.

cupied nesting areas in the NCA with known nesting outcomes and without radio-tagged adults (1992, N = 23; 1993, N = 19; 1994, N = 21). A nesting area was considered "occupied" if we observed territorial activity, courtship, brood rearing activity, eggs, young or conspicuous field sign (e.g., whitewash at a roost). Control and treatment nesting areas were interspersed along the Snake River Canyon.

We attached transmitters as backpacks using a Teflon® ribbon harness (after Buehler et al. 1995). Details of harness construction and fitting are found in Vekasy et al. (1996). A transmitter with harness weighed 75 g, less than 3% body weight for males ($\bar{x}$ = 3691.5 g, SE = 98.9, N = 10), and less than 2% body weight for females ($\bar{x}$ = 4412.5 g, SE = 133.4, N = 4).

We observed Golden Eagle nesting areas from a helicopter two or three times throughout the season to determine occupancy and egg laying, and number of nestlings ≥51 d old (brood size). We surveyed nesting areas from the ground when we could not determine these parameters by helicopter. We considered pairs as nonlaying if there was no evidence that eggs were laid and a bird was not seen in an incubating posture on a nest. The presence of one member of a pair in incubating posture, or eggs or young in a nest was considered a nesting attempt. Nesting attempts were considered successful if at least one nestling reached 80% of fledging age (Steenhof 1987), or approximately 51 d.

We classified degree of exposure at each nest site when possible. Nest shading was classified as the percent of a nest in shade between 1200 H and sunset. Nests were classified as shaded if >25% of a nest was shaded, intermediate if 6–25% was shaded and exposed if ≤5% was shaded.

We observed nesting areas with radio-tagged eagles once every one to two weeks to assess behavior and habitat use during foraging. One observer remained in the canyon near the nest while the other was positioned outside the canyon to follow an eagle by vehicle during forays. We did not follow and observe eagles in control areas.

We used a three-factor (treatment, year, nesting success) log-linear model to test for the effect of radio-tagging (treatment) on nesting success (number of pairs successful/occupied territory) among years. We used a one-factor (treatment) ANOVA with a repeated measure (year) to test for differences between the number of young produced by control and radio-tagged pairs at occupied nesting areas. We used a repeated-measure ANOVA because the same eagles were monitored each year. We used a two-factor (year and treatment) ANOVA to analyze the brood size of successful control and radio-tagged eagles. Sample sizes were too small to use the repeated measures ANOVA for brood size, and treating the data as independent may have inflated the significance of this test.

Small sample sizes of radio-tagged and control eagle nests made conventional significance tests of shading differences suspect, so we analyzed differences in shade characteristics between radio-tagged and control eagle nests using permutation tests (Manly 1991; StatXact software) on each year separately. Nests classified as shaded or intermediate were combined and compared to exposed nests.

We used a one factor (treatment) ANOVA to compare the historical likelihood of nesting successfully between treatment and control nesting areas. Historical likelihood of successful nesting (number of years successful/all years occupied) during 1970–91 was calculated for nine treatment territories and 19 control areas. For this calculation, we excluded controls with more than five consecutive vacancies between 1970–91, or consecutive vacancies in 1992 and 1993 because such nesting areas were also avoided during radio-tagging. This is a conservative bias that excludes extremely unproductive control territories because such territories would not have been selected for radio-tagging. We also excluded one control nesting area with a radio-tagged male present from 1975–80. At nesting areas with past research disturbances, we excluded cases where productivity might have been influenced, including treatment of nestlings for parasites, placement of shade devices and trapping and radio-tagging of adults.

RESULTS

Over all years, tagged and control eagles had similar nesting success (39% of 23 tagged and 51% of 63 control nests were successful). However, differences in nesting success between radio-tagged and control eagles varied significantly among years (3-way interaction of treatment, year and fate: $G_2 = 5.82$, $P = 0.054$, Fig. 1). Radio-tagged eagles had similar nesting success compared to control eagles in 1992, but success of radio-tagged eagles was much lower than control eagles in 1993. In 1994, radio-tagged eagles had slightly higher nesting success than control eagles.

The timing of failures varied among years. In 1992, all seven radio-tagged pairs laid and hatched eggs (100%). In 1993, eight of nine (88.9%) tagged eagles laid eggs and four (50%) hatched eggs. In 1994, six of seven (85.7%) tagged pairs laid eggs and four (66.7%) hatched eggs. The percentage of nonlaying control and radio-tagged pairs, respectively, was 17.4% ($N = 4$) and 0.0% ($N = 0$) in 1992, 10.0% ($N = 2$) and 11.1% ($N = 1$) in 1993, and 38.1% ($N = 8$) and 14.3% ($N = 1$) in 1994.

Number of fledglings produced in occupied territories was associated with tagging and year ($F_{2,22} = 5.07$, $P = 0.016$). Radio-tagged eagles produced fewer fledglings than control eagles in 1993, but their productivity was the same or slightly higher during 1992 and 1994 (Fig. 1). Combining radio-tagged and control eagles, brood size did not vary among years ($F_{2,35} = 2.04$, $P = 0.15$).

The degree of shading at nests did not differ between radio-tagged and control eagles. Between 1992 and 1994, control and treatment groups had similar proportions of exposed nests (1992, 36.8%, $N = 19$, 28.6%, $N = 7$; 1993, 38.9%, $N = 18$, 62.5%, $N = 8$; 1994, 38.5%, $N = 13$, 40.0%, $N = 5$; $G_2 = 1.15$, $P = 0.56$).

Historical nesting success of treatment and control territories did not differ ($F_{1,26} = 0.003$, $P = 0.95$). The nesting success between 1971–91 was 50.2% ($N = 9$) for treatment territories and 49.8% ($N = 19$) of control territories.

DISCUSSION

Decreased Golden Eagle productivity (nesting success, fledglings per occupied territory and brood size) was associated with the presence of a radiotransmitter, but this was significant during only the 1993 breeding season. This is in contrast to Prairie Falcons (*Falco mexicanus*), which carried similar transmitters without negative effects on productivity (Vekasy et al. 1996). The stress of capture did not appear to inhibit nesting success, as most eagles were captured in the winter of 1991–92, and no radio-tagging association with success was apparent during the 1992 breeding season. Male eagles captured at two nesting areas in 1993 both had mates that laid eggs, but both were unsuccessful. One female captured in both 1993 and 1994 did not lay eggs in either year. Effects of capture and handling may be more evident when coupled with other year-dependent stresses. The timing of capture within a winter or the sex of the bird tagged may also influence effects, but our sample size is too small to quantify this.

Golden Eagle productivity appears to be related to jackrabbit density. The variable effect of radio-tagging on productivity in eagles may be related to the dynamics of prey population fluctuations. The strongest association between tagging and success occurred during a precipitous decline in jackrabbit densities (1992–93). We detected no association between tagging and success during a slight recovery from low jackrabbit densities (1993–94) or during years of high jackrabbit densities (1991–92). Radio-tagged eagles may be especially sensitive to changes in prey densities. During periods of low prey densities, foraging opportunities may be reduced, and transmitter loads can decrease maneuverability (Gessaman and Nagy 1988) and may decrease foraging success.

Weather and nest shading may have interacted with low prey populations to reduce radio-tagged eagle nesting success in 1993. Although nest shading did not differ significantly between treatment

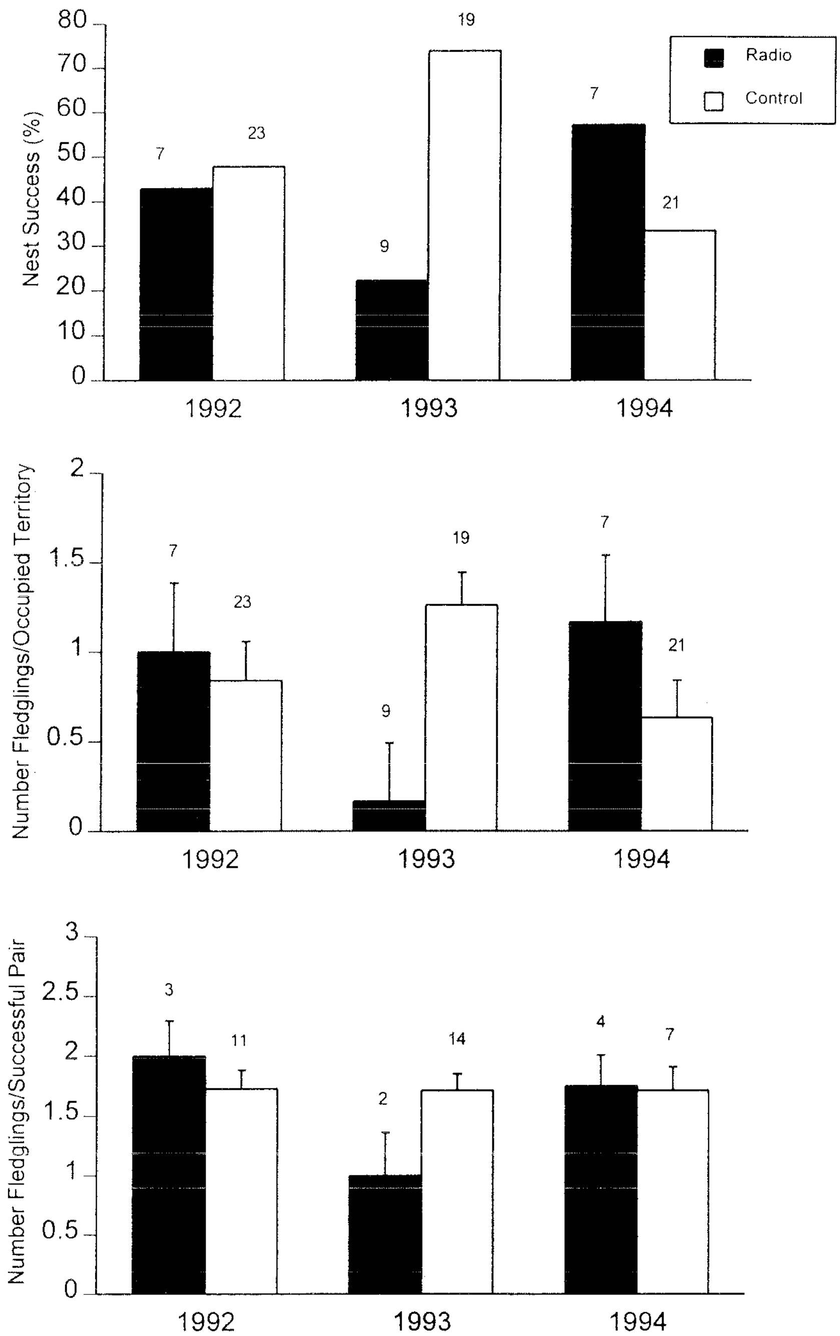

Figure 1. Radio-tagged and control Golden Eagle nesting success for all occupied nesting areas and mean (±SE) number of fledglings (nestlings ≥51 d old) per occupied territory and per successful pair. Sample sizes (numbers of pairs) are given above error bars.

and control nests, treatment nests in 1993 had the highest percentage of exposed nests (62.5%). Aside from having the lowest prey densities during our study, the spring of 1993 was also very cool and wet (NOAA 1993). Wet weather has been associated with poor foraging success in raptors (Adamcik et al. 1979, Kostrzewa and Kostrzewa 1990), and low prey and poor foraging conditions may disproportionately reduce foraging success of radio-tagged eagles compared to controls. Females we studied left the nest unattended while males were absent and may have left more frequently or for greater durations because of food stress. This may leave eggs and small chicks exposed and could decrease their survival during extreme weather conditions (Mosher and White 1976).

Small sample size may have had the greatest influence on whether or not we detected an effect of radio-tagging on Golden Eagles. We attempted to reduce some of the bias associated with small sample size by comparing historical nesting success between treatment and control territories. However, a slight change in the composition of our sample can have large effects. For example, two radio-tagged pairs had subadult mates in 1993, and both were unsuccessful. Steenhof et al. (1983) found that pairs of Golden Eagles with at least one subadult member had lower nesting success compared to adult pairs. If the age composition of pairs in 1993 had been different or both pairs with subadults had been successful, we may not have detected any difference in nesting success between radio-tagged and control eagles.

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