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POST-FLEDGING SURVIVAL AND DISPERSAL OF PEREGRINE FALCONS DURING A RESTORATION PROJECT

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ABSTRACT.—We monitored 38 juvenile Peregrine Falcons (*Falco peregrinus*) up to 3 mo immediately after their release from a hack box during 1999–2000. The restoration site was a cliff near Eagle Point Park in Dubuque, Iowa. Falcons were released in a staggered manner from mid-June until late July each summer. Older falcons remained at the site longer than at previous urban releases and interacted with the younger falcons. The four mortalities (11%) confirmed during the observation periods were discovered and reported by citizens near the release site. We used radiotelemetry, observations of color-marked birds at the hack site, and recovered mortalities to estimate weekly survival rates and dispersal patterns. We estimated weekly survival rate to be 0.988 (SE = 0.01), and our weekly resighting rate was high: 0.885 (SE = 0.03). Juveniles were observed for an average of 4.3 wk in 1999 (SD = 2.5), but only 3.4 wk in 2000 (SD = 2.3). Accordingly, weekly fidelity rates were year-specific: 0.903 (SE = 0.03) in 1999 and 0.795 (SE = 0.05) in 2000. No mortalities were attributed to Great-horned Owl (*Bubo virginianus*) predation, but substantial numbers of owls were seen in summer 2000. The presence of owls in 2000 may have contributed to the difference in fidelity rates and dispersal patterns between years.

KEY WORDS: *Peregrine Falcon;* Falco peregrinus; *survival; dispersal; mark-recapture model; population restoration.*

Sobre vivencia de volantones y dispersión de halcones peregrinos durante un proyecto de restauración

RESUMEN.—Monitoreamos 38 halcones peregrinos (*Falco peregrinus*) juveniles hasta 3 meses inmediatamente después de su liberación desde una "caja de suelta" durante 1999–2000. El sitio de restauración era un risco cerca la parque Punto del Águila en Dubuque, Iowa. Los halcones fueron liberados en forma escalonada desde mediados de junio hasta finales de julio de cada verano. Los halcones más adultos permanecieron por más tiempo en los sitios urbanos en los cuales interactuaron con los halcones más jóvenes. Las cuatro muertes (11%) confirmadas durante los períodos de observación fueron descubiertas y reportadas por ciudadanos cerca a los sitios de liberación. Utilizamos la telemetría y las observaciones de aves marcadas con colores en los sitios de liberación. La recoleccion de animales muertos fue utilizada para estimar la tasa de sobrevivencia semanal y los patrones de dispersión. Estimamos la tasa de sobrevivencia semanal en 0.988 (SE = 0.01), y una tasa de avistamientos semanal alta: 0.885 (SE = 0.03). Los juveniles fueron observados en un promedio de 4.3 por semana en 1999 (SD = 2.5), pero solo fue de 3.4 en el 2000 (SD = 2.3). En concordancia, las tasas de fidelidad semanal fueron especificas para cada año: 0.903 (SE = 0.03) en 1999 y 0.795 (SE = 0.05) en el 2000. No hubo mortalidades atribuibles a la depredación por parte de *Bubo virginianus.* Sin embargo, un número importante de búhos fue observado en el verano del 2000, lo que pudo haber contribuido a las diferencias en las tasa de fidelidad y en los patrones de dispersión entre años.

[Traducción de César Márquez]

Peregrine Falcons (*Falco peregrinus*) once nested on ledges of bluffs along Iowa rivers, but they were extirpated in the 1950s and 1960s. Recovery efforts in urban areas have been successful, by using tops of tall city buildings as hack sites to release captive-hatched juveniles. Because of efforts in Iowa and surrounding states, the Midwestern population had grown to 67 territorial pairs by 1997, with 747 captive-produced juveniles released (Tordoff and Redig 1997). As of 2002, Peregrine Falcons are still

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listed as an endangered species in Iowa. In 1998, the Iowa Department of Natural Resources (DNR) began a program of cliff-habitat releases. During the summer of 1999, the city of Dubuque, IA became the site of Iowa's second cliff release.

Juveniles are hacked in the absence of their parents. Therefore, humans feed the juveniles with farm-raised quail carcasses, and the hatchlings interact with their siblings to learn flying and hunting skills, much as they would in the presence of their parents (Sherrod et al. 1981). Great-horned Owl (*Bubo virginianus*) predation has been a key factor in the success of previous releases (Barclay and Cade 1983, Redig and Tordoff 1988). Our project was developed to monitor the survival and dispersal of juveniles from the hack site area in the context of (1) a relatively large cliff release and (2) concerns of owl predation.

Natal dispersal is the movement from the hatch site to a breeding territory (Greenwood and Harvey 1982), and previous studies have reported on Peregrine Falcon natal dispersal (e.g., Tordoff and Redig 1997, Restani and Mattox 2000). Although natal dispersal is often used as an indicator of recruitment success, the period immediately following fledging may be the most critical to the survival of juvenile Peregrine Falcons (Barclay and Cade 1983). In this paper, we refer to this period as the "post-fledging period," and we use the dispersal of the juveniles away from the hack site as the functional end of this period.

Very little information has been published on the survival and movements of juvenile Peregrine Falcons during the post-fledging period (but see Perez and Zwank [1995] for Aplomado Falcons [*Falco femoralis*]). Our goal was to determine the initial viability of the juvenile falcons released by the Iowa DNR at the cliff hack site. To do this, we monitored movements, determined habitat use, and estimated survival during the post-fledging period, prior to migration.

METHODS

We conducted this study during June–September of 1999 and 2000 in Dubuque County, Iowa (42°30′N, 90°38′W). We placed two hack boxes at the top of a 50-m, east-facing cliff, on the Mississippi River, just below Lock and Dam 11 (Fig. 1). Birds were released in a staggered manner beginning on 22 June 1999 and 20 June 2000 (Fig. 2).

Prior to release, we banded each juvenile with a unique color- and alpha-numerically-coded leg band, in addition to the National Bird Banding lab's (USGS-BRD) anodized band. We also color-marked each juvenile on either the wing or tail with non-toxic paint. For individuals marked on a single wing, we also marked the opposite side of the head, behind the eye, to allow observers to determine identity from any angle.

We monitored color-marked birds at the hack site from an observation point below the cliff, using a spotting scope and binoculars. Observations were taken daily, usually at 0600–0830 H, 1100–1300 H, and 1800–2030 H

During 1999, we radio-marked five individuals with leg-mounted transmitters. Because the falcons were able to remove the leg-mounted transmitters, we switched to backpack harnesses on four individuals during 2000. We determined the location of radio-marked birds by triangulating with at least two bearings, once each day following release; bearings were taken from six fixed points surrounding the cliff site. We used Magellan GPS receivers to determine the coordinates of the fixed points, and we used LOCATE II software to estimate the actual coordinates of each bird from the bearing data (Nams 1990). We mapped the position of each bird using ArcView GIS software, version 3.2, and determined home range using the Jennrich-Turner home range algorithm (Jennrich and Turner 1969) within ArcView as an extension (Hooge and Eichenlaub 1997). Compared to other home range estimators, the Jennrich-Turner method is especially useful for determining confidence intervals of home range size and deriving the axes of groups of location coordinates (Hooge and Eichenlaub 1997).

We calculated the proportion of fatalities in our sample based on documented deaths. We calculated 95% confidence intervals (CI) for each binomial sample proportion (Burleson 1980). To facilitate comparisons with other studies, we also calculated an adjusted proportion of fatalities by considering birds that disappeared from the hack site within the first two weeks after release as dead (three of our confirmed mortalities happened in the first week and one happened in the third week). The latter method incorporates many biases and assumptions, and we suggest is a "worst case" scenario.

Just as we do not know what happened to birds that disappeared during the first 2 wk, surveys of most wildlife populations are unable to detect all animals in the intended population. To estimate the probability of surviving a given time interval robustly, it is necessary to use methods which adjust for incomplete detectability (Thompson et al. 1998). Therefore, we summarized our resighting data into weekly discrete time intervals for analysis in a Cormack-Jolly-Seber mark-recapture design (Pollock et al. 1990). This method allows the estimation of weekly survival rates (the probability of surviving one week), as well as other parameters.

We estimated demographic parameters using recovery data from dead birds and resighting data from live birds in the same estimating model (Burnham et al. 1987) in program MARK (White and Burnham 1999). In addition to the usual survival and resighting (the probability of being detected during a week given that the animal is alive) parameters, the incorporation of known deaths to the data set allowed the estimation of a fidelity parameter (ψ, the probability of remaining at the site during a given week; Burnham et al. 1987). We considered several potential models that varied by whether parameters were year-specific or pooled across the 2 yr (Table 1). Because

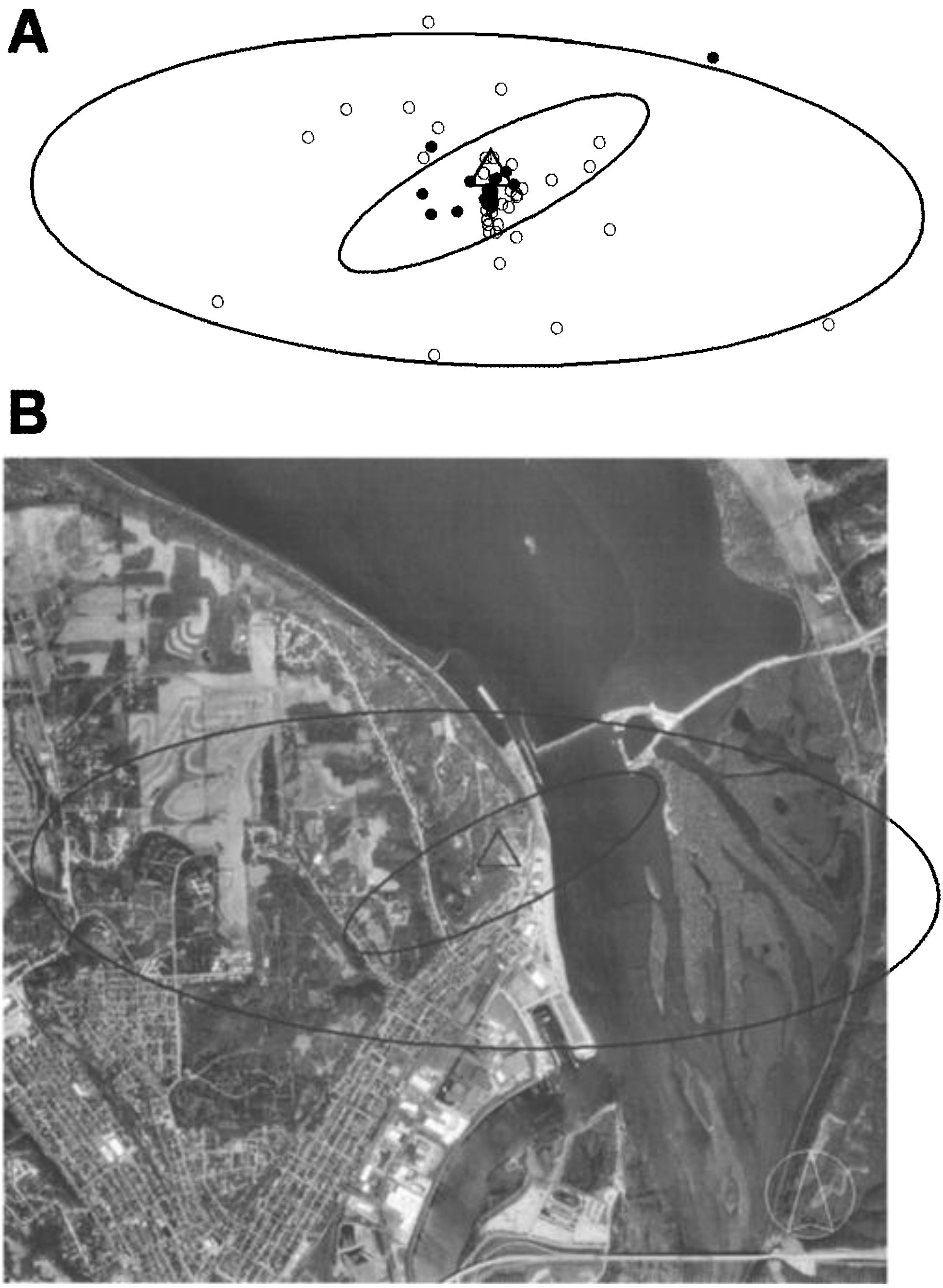

Figure 1. Ranges and locations of radio-marked, juvenile peregrine during 1999–2000 (A), immediately following release from a hack site (△) at Eagle Point Park in Dubuque, IA along the Mississippi River (B). Ellipsoids indicate 95% of home range as determined by the Jennrich-Turner method (Jennrich and Turner 1969); small ellipsoid is for 1999 and large ellipsoid is for 2000.

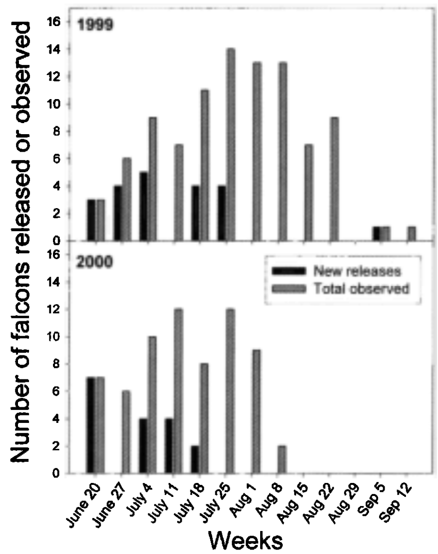

Figure 2. Numbers of juvenile Peregrine Falcons released and total numbers observed at the hack site during 1999–2000 at Eagle Point Park in Dubuque, IA.

of small cohort sizes, we used a corrected Akaike Information Criterion (AIC_c) to select the best estimating model (Burnham and Anderson 1998). We extrapolated ($\hat{S}_{10\text{-wk}} = \hat{S}_{wk}{}^{10}$, $\hat{S}_{annual} = \hat{S}_{wk}{}^{52}$) our weekly estimates to obtain 10-wk (post-fledging period) and annual survival estimates for comparison with other studies. We used the delta method for approximating variances for these extrapolated survival estimates (Weir 1990).

Table 1. Alternate models and model selection data from recoveries and resightings of juvenile Peregrine Falcons following release from a hack site in Dubuque, IA, summers 1999–2000. Each model resulted in estimates of survival (S, probability of surviving the week), resighting rate (p, probability of live birds being detected), recovery rate (r, probability of dead animals being reported), and fidelity rate (Ψ, probability of remaining at the hack site during the week). Falcons were grouped in two cohort groups by year of release; models varied by either estimating two year-specific parameters (g) or one pooled parameter (.) across years. Models were ranked by AIC values (see text), and the ΔAIC_c column shows the difference between the best model (row 1) and the alternate models' (rows 2–8) AIC values.

MODEL	ΔAIC_c	AIC WEIGHT[a]	N PARAMETERS
{S(.) p(.) r(.) Ψ(g)}	0.00	0.2786	5
{S(.) p(.) r(.) Ψ(.)}	1.29	0.1464	4
{S(g) p(.) r(.) Ψ(g)}	1.91	0.1074	6
{S(.) p(g) r(.) Ψ(g)}	2.16	0.0947	6
{S(.) p(.) r(g) Ψ(.)}	2.79	0.0690	5
{S(g) p(.) r(.) Ψ(.)}	3.16	0.0573	5
{S(.) p(g) r(.) Ψ(.)}	3.33	0.0528	5
{S(g) p(g) r(g) Ψ(g)}	6.31	0.0117	8

[a] AIC Weight is the weight of evidence in favor of the given model being from the set of models considered. AIC Weight is a function of the model's ΔAIC_c value, compared to the other models' ΔAIC_c values (Burnham and Anderson 1998). In our data set, the best model is twice as likely (0.2786 compared to 0.1464) as the second-best model to be the best model.

RESULTS

We released 38 juvenile Peregrine Falcons; 21 in 1999 and 17 in 2000 (Fig. 1). During 1999, we observed Great-horned Owls only once near the hack site, but we observed them at least eight times in 2000.

Survival. We documented four deaths (10.5%, 95% CI = ±10%) during the two post-fledging periods (1999 and 2000); by incorporating six other birds that disappeared before 2 wk the adjusted (worst-case scenario) mortality estimate was 26.0% (95% CI = ±14%). Three of 21 juveniles (14.3%, 95% CI = ±11%) were known to have died in 1999, and 1 of 17 (7.1%, 95% CI = ±7%) was found dead in 2000. The fatalities in 1999 consisted of (1) hypothermia from becoming trapped in a livestock watering tank, (2) overcome by fumes after entering a garbage dumpster recently treated with chlorine tablets, and (3) an assumed mammal predation. In the latter case, skeletal remains were found with skull intact. We used electric fencing immediately around the hack site to dissuade mammal scavengers, and several raccoons (*Procyon lotor*) and a red fox (*Vulpes vulpes*) were seen near the hack site. The death in 2000 resulted from an electrocution on a power pole; several falcons were seen using the utility pole as a roost prior to the mortality. No detected fatality appeared to be the result of Great-horned Owl predation. The mean distance of the four deaths from the hack site was 676 m (SD = 411).

Weekly survival ($\hat{S}$ = 0.988, SE = 0.01) did not differ between years, and our weekly resighting probability (p) was also constant between years (p = 0.885, SE = 0.03; Table 1). Extrapolating the weekly survival to the entire post-fledging period resulted in a 10-wk survival rate of $\hat{S}$ = 0.886 (SE = 0.07, or a 0.114 mortality rate estimate for the same 10-wk period); assuming constant survival for the first year would result in an annual survival estimate of $\hat{S}$ = 0.534 (SE = 0.84).

Dispersal. We observed first-year juveniles at our hack site from 22 June–12 September in 1999 and from 20 June–9 August 2000 (Fig. 2). No juveniles from 1999 were observed in 2000, and no juveniles from either year were observed at the site in summer 2001.

Individual juvenile falcons were observed for a mean of 4.3 wk (SD = 2.5) during 1999, and for a mean of 3.4 wk (SD = 2.3) during 2000 ($F_{1,38}$ = 2.82, P = 0.10). Weekly fidelity (ψ) the probability of not dispersing from the hack site during the week) was lower in 2000 (1999: ψ = 0.903, SE = 0.03; 2000: ψ = 0.795, SE = 0.05; Table 1).

Habitat Use. We observed color-marked birds most often at the hack boxes. However, the juveniles also used the cliff face for roosting, feeding, and social interactions. In addition, we observed juveniles in trees surrounding the hack site. In 1999, 23 of the 28 (82%) "non-hack site" observations were from the cliff face; 5 of the 28 (18%) were from trees. In 2000, only 31 of 72 (43%) "non-hack site" observations were from the cliff face; 41 of the 72 (57%) were from the trees (χ^2 = 5.56, df = 1, P = 0.018).

In 1999, we obtained 17 sets of useable bearings from radio-marked birds before the leg-mounted radios fell off the birds. The birds were observed picking at the leather/cotton thread attachments, and were soon able to dislodge the transmitters; otherwise, all behaviors of radio-marked birds were normal. In 2000, we obtained 40 sets of useable bearings; apparent signal bounce from the cliff walls prevented program LOCATE II from determining a precise location estimate for other sets of bearings. Birds remained closer to the cliff and hack site during 1999 than in 2000. The mean distance of radio-marked birds from the hack site was 268 m (SD = 296.2) during 1999; in 2000, the mean distance was 619 m (SD = 871, t = 2.26, df = 53, P = 0.03; Fig. 1). In 1999, the minimum distance from the hack site was 72 m and the maximum was 1342 m; in 2000, the minimum was 52 m and the maximum was 5329 m. The number of useful sets of bearings per bird ranged from 1–8 in 1999, and from 4–22 in 2000; the backpack harnesses in 2000 provided more useful data, although one fell off prematurely.

Movements of young peregrines were more often in an east-to-west direction ("inland" from the river), than in a north-to-south direction (along the river). The home range ellipsoid, representing 95% of their daily use, for birds in 1999 was 75 ha, and measured 1861 m southwest-to-northeast and 512 m northwest-to-southeast; in 2000 the home range ellipsoid was 682 ha, and measured 4839 m east-to-west and 1795 m north-to-south. In both years, the ellipsoid covered Eagle Point Park, Mississippi River, islands on the river, and some urban area. At least 50% of the area was covered by the forested Park (Fig. 1).

DISCUSSION

We did not design this study to measure the effects of Great-horned Owls on juvenile Peregrine Falcons. However, the increased presence of owls at the hack site in 2000 suggests rationale for the observed changes in peregrine behavior. In 2000, when more owls were seen, peregrine juveniles had lower site fidelity, shorter mean observation periods, increased daily distance from the hack site, and greater use of more secluded perch sites (trees). However, survival did not seem to be affected by the presence of the owls. Availability of quail at the hack site may have attracted the owls, while also satisfying the owls' dietary needs (thus, reducing predation pressure on the falcons). At the least, our study provides evidence that peregrine restoration projects can be carried out successfully in the presence of Great-horned Owls (but see Craig et al. 1988, Redig and Tordoff 1988).

The Iowa Department of Natural Resources considered this release to be successful for several reasons, including high post-fledging site fidelity and survival. Juveniles from previous urban releases in Iowa have left the hack site much earlier (ca. 2 wk) than the juveniles from Dubuque's natural cliff site (P. Schlarbaum pers. comm.). The longer time spent at the hack site during the post-fledging season could provide for higher survival to the migratory period. Juveniles remained at hack sites in Canada for a mean of 22.9–27.7 d (Fyfe 1988) and from 4–7 wk in Sweden (Lindberg 1988), compared to our observations of 4.3 wk (30 d) in 1999 and 3.4 wk (24 d) in 2000. Fyfe (1988) also reported that birds remained longer at the site of multiple releases, similar to ours.

Radio-marked juveniles in this study had a much more limited range than juveniles or adults in other studies. For comparison, Enderson and Kirven (1983) reported long (≥1 km) daily movements for an adult male. Jenkins and Benn (1998) reported mean flights of 10.3–21.9 km for adult males and females, with a mean home range of 123 km². Perez and Zwank (1995) found dispersal flights of 2–16 km for juvenile Aplomado Falcons in Texas. The farthest distance we recorded a falcon from the hack site was just over 5 km, and the combined home range for our group of falcons in 2000 was just 472 ha. The continued presence of food at the hack site, in addition to forest habitat concentrated near the Mississippi River probably contributed to this observation.

Approximately 90% of all juveniles survived the 10-wk post-fledging period, and the sources of mortality were similar to those reported by Barclay and Cade (1983). Our observed mortality of 10.5% was very similar to the 10-wk mortality rate of 11.4% estimated using the mark-recapture model. The survival of these juveniles was high compared to other estimates. Burnham et al. (1988) estimated that 81% of hacked young survived three weeks in the Rocky Mountain region during 1976–85; our survival over 3 wk would be 96.4%. Barclay and Cade (1983) used estimates from other raptor species to arrive at an approximation of 75% survival during the pre-dispersal period—the same as our worst-case scenario estimate. Tordoff and Redig (1997) used resightings of Peregrine Falcons to estimate a minimum first-year survival estimate of 23%, although many survivors were probably not resighted. Our extrapolated first-year survival rate of 53% could potentially be lowered by migratory mortalities. However, the period we monitored may be the most hazardous for juveniles without parental protection (Barclay and Cade 1983); all of our documented fatalities occurred during the first 1–3 wk following fledging. Thus, annual survival could actually be higher than 53% for the birds we monitored. For comparison, Tordoff and Redig (1997) reported a survival rate of 86% for adults in the Midwest; they also determined that hacked juveniles survived at better rates than wild juveniles in the Midwest.

Juvenile survival rates are critical, because a low proportion of available individuals are recruited into the breeding population (Tordoff and Redig 1997, Restani and Mattox 2000). With 38 juveniles released in one location and high survival rates, the cliffs near Dubuque, IA on the Mississippi River have high potential to host a breeding pair in the near future.

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