J. Raptor Res. 41(1):61–65

Survival, Mortality, and Morbidity Among Peregrine Falcons Reintroduced in Kentucky

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Key Words: *Peregrine Falcon*; Falco peregrinus; *morbidity*; *mortality*; *survival*; *wildlife reintroduction.*

A primary goal of wildlife reintroduction is to reestablish populations of conservation concern (Kleiman 1989). Achieving this goal depends on the fate of reintroduced individuals. Several raptor species, including the Peregrine Falcon (*Falco peregrinus*), have been reintroduced using a release technique known as hacking. Hacking involves housing juveniles in enclosures at the release site for several days before release. Typically, hacked raptors remain in the vicinity of the hacking station for several weeks after release and then initiate dispersal; the time between fledging and departure is known as the post-fledging period. This period is a critical life-history stage for hacked raptors as they lack the protection and information transfer that characterizes parental influence among wild raptors. This absence of parental influence could affect survival and behavioral development (Newton 1979, Sherrod 1983). Sherrod et al. (1982) reported that a post-fledging period

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Table 1. Survival $\hat{S}[t]$[a] of reintroduced Peregrine Falcons (N = 33) during a 6-wk post-fledging period in Kentucky, 2001–03.

			Worst Case[b]		Intermediate Case[b]		Best Case[b]	
Week	(t) Deaths	Censored	$\hat{S}$ [t]	95% C.I.	$\hat{S}$ [t]	95% C.I.	$\hat{S}$ [t]	95% C.I.
1	2	9	0.67	0.54–0.80	0.94	0.86–1.02	0.94	0.86–1.02
2	3	0	0.55	0.39–0.70	0.81	0.66–0.96	0.85	0.73–0.96
3–6	0	0	0.55	0.38–0.72	0.81	0.65–0.97	0.85	0.73–0.97

[a] Pooled among years 2001–03.

[b] Worst-case scenario considers premature departure from hacking areas to represent mortality in survival calculations; intermediate-case involves censoring of premature dispersals from survival calculations; best-case scenario includes only known mortalities in survival calculations.

of 3–5 wk is optimal for development of skills necessary for survival in peregrines. A post-fledging period of <2 wk is probably not adequate for development of these skills (Sherrod 1983, Powell et al. 2002). Thus, peregrines that disperse sooner than 2 wk after release might exhibit reduced first-year survival compared to those that spend more time on the post-fledging area. Survival in peregrines has been examined as part of long-term band recovery studies (Tordoff and Redig 1997, Kauffman et al. 2003), by counting the proportion of juveniles that achieve independence (Barclay and Cade 1983, Lanier et al. 1983, Burnham et al. 1988, Craig et al. 1988), and by using telemetry (Powell et al. 2002).

The peregrine has recovered in much of North America (Corser et al. 1999, Tordoff et al. 2000), but recovery in the southeastern U.S. has progressed more slowly than in other regions. Of the recovery regions designated by the United States Fish and Wildlife Service (FWS), the southeast (FWS Region four) supports the fewest breeding pairs of Peregrine Falcons (ca. 18 pairs), despite a record of >70 historical eyries (Dzialak et al. 2005a). As part of an effort to restore the peregrine in Kentucky and augment regional breeding locations, we reintroduced 33 peregrines in cliff habitats in eastern and central portions of the state. The objectives of this study were to quantify survival among peregrines reintroduced in Kentucky, and to examine survival estimates under several scenarios that account for variability in the amount of time spent on the post-fledging area (PFA). We also describe causes of mortality and characteristics of morbidity.

Study Area and Methods

We released peregrines at Red River Gorge Geologic Area, Daniel Boone National Forest in eastern Kentucky, and Tom Dorman State Nature Preserve in central Kentucky. Daniel Boone comprises 10 500 ha and is located on the western fringe of the Cumberland Plateau in eastern Kentucky. Rugged topography, steep slopes with mixed mesophytic and northern hardwood forest (*Tsuga canadensis, Liriodendron tulipifera, Fagus grandifolia*), and massive sandstone outcrops that form broad ridge-tops with oak-pine forest (*Quercus* spp., *Pinus* spp., *Carya* spp.) characterize the region. Dorman Preserve comprises 229 ha and is located adjacent to the Kentucky River in the Bluegrass physiographic region in central Kentucky. Gently rolling terrain characterizes the Bluegrass region, but in some areas the Kentucky River carves a deep channel exposing limestone bluffs. Dominant flora includes mesophytic and riparian forest (*Fraxinus quadrangulata, Quercus muehlenbergii, Acer saccharum, Ulmus thomasi, A. saccharinum, Platanus occidentalis*).

Peregrines were hacked following protocols outlined in Sherrod et al. (1982). Prerelease veterinary evaluation and health certification of all peregrines was coordinated through propagators and the University of Minnesota College of Veterinary Medicine Raptor Center. Each bird was fitted with a tarsal-mounted RI-2CM transmitter (Holohil Systems, Ltd., Ontario, Canada). Transmitters were equipped with mortality sensors set to alter the transmission rate after 12 hr of inactivity. Transmitter life was 90 d, and total unit mass including transmitter and tarsal mount was ca. 10.0 g (1.0–3.0% of body mass). Monitoring was initiated immediately after release and peregrines were relocated 1–5 times daily using aerial telemetry and ground reconnaissance until departure from the release area or mortality. Telemetry flights were conducted in a Cessna 182 equipped with wing strut-mounted two-element yagi antennae, generally at altitudes of 615–1250 m above sea level. We used an R-1000 telemetry receiver (Communications Specialists, Inc., Orange, CA U.S.A.) to relocate peregrines, and location estimates were recorded using a hand-held Global Positioning System (Garmin GPS III, Olathe, KS U.S.A.). Details on hack site selection and post-release monitoring can be found in Dzialak et al. (2005a, 2005b).

We used the Kaplan–Meier product-limit method to estimate post-fledging survival (Kaplan and Meier 1958, Pollock et al. 1989). We considered the time of origin to be the date of release and we examined survival for 6 wk post-release. We estimated survival functions for what we considered best-case, intermediate-case, and worst-case scenarios. Best-case survival functions included only known mortality. Intermediate functions included known mortality and censorship of individuals departing from the hack areas within 14 d of release (Powell et al. 2002). Worst-case functions considered individuals departing within 14 d of release to be dead in addition to known mortality. We used the Tarone–Ware log-rank test to assess differences in survival between sexes (Cox and Oakes 1984). Sample size was too low to assess and compare survival among years or between sites using the Kaplan–Meier product-limit approach, so we made comparisons among years and between sites based on the number of peregrines achieving independence using the Fisher exact test. We examined whether risk of mortality varied during the post-fledging period by converting Kaplan–Meier survival functions to a cumulative hazard function (Todd et al. 2003). We delineated intervals of constant slope based on visual examination of the cumulative hazard function and tested for differences between intervals using the log-rank chi-squared statistic. Significance was set at $P \leq 0.05$. We made an effort to recover transmitters in mortality mode as soon as possible. Dead peregrines and those recovered in poor health were examined by a veterinarian to determine cause of mortality or morbidity and, when possible, transferred to a raptor rehabilitator for treatment and release.

RESULTS

We released 12 peregrines in 2001, 10 in 2002, and 11 in 2003. We released 28 peregrines at Daniel Boone and five at Dorman Preserve. The number of Peregrine Falcons achieving independence did not differ among years (df = 2, $P = 0.72$) or between sites (df = 1, $P = 0.70$). There were five confirmed mortalities during the program; all occurred pre-departure from the hack areas. In addition to these five mortalities, nine peregrines dispersed from the PFA prematurely (e.g., spent <14 d on the PFA). There was no difference in survival functions between sexes ($N = 19$ males and 14 females; $\chi^2 = 0.54$, df = 1, $P = 0.46$). Overall post-fledging survival for the program was 0.55, 0.81, and 0.85 for worst-case, intermediate-case, and best-case scenarios, respectively (95% C.I.: 0.38–0.72, 0.65–0.97, and 0.73–0.97, respectively; Table 1). The worst-case estimate differed from intermediate- and best-case estimates based on 95% C.I.; however, the difference between intermediate- and best-case estimates is negligible considering that the fate of birds that left the hack areas prematurely is unknown. Based on the cumulative hazard function, there were two time intervals that reflected different daily risks of mortality ($\chi^2 = 6.59$, df = 1, $P = 0.01$). The first phase included the initial 14 d after release and was associated with the greatest daily mortality risk. The second phase included time spent on the PFA after 14 d post-release. All mortality occurred during the first phase. No known mortality occurred among peregrines released at Dorman Preserve. Causes of mortality at Daniel Boone were undetermined. We tracked four of five transmitters in mortality mode to inaccessible crevices located on a cliff face midway between the ridge-top and the valley floor. We recovered only one carcass.

We recovered one peregrine that departed normally after spending 18 d on the PFA, but was shot 180 km west of the hacking station. This bird had sustained projectile wounds to the right ventral abdomen and to the distal right ulna resulting in an oblique fracture of the ulna. The peregrine was treated, rehabilitated, and later released successfully near the location of its recovery. The shot peregrine was included in analyses as a successful disperser.

DISCUSSION

Regional peregrine hacking programs typically report the proportion of juveniles that achieve independence. Generally, this proportion has been 0.63–0.83 in North America (Barclay and Cade 1983, Lanier et al. 1983, Henry 1987, Craig et al. 1988, Therres et al. 1993). Survival-to-departure from PFA rates are easy to interpret and are appropriate to present as a measure of effectiveness in initial species recovery efforts, but this rate will not always reflect the true efficiency of the release effort. For example, survival-to-departure among peregrines we released in Kentucky was 0.85, but it is possible that several birds that departed the PFA prematurely lacked skills necessary for survival and succumbed to starvation. Conversely, it is probably not accurate to assume that all early departing falcons die, particularly those individuals that may have remained on the post-fledging area for 10–13 d as opposed to 2–3 d. In fact, some data suggest that individuals that disperse earlier from their natal areas may be in better physical condition than late dispersers (Belthoff and Dufty 1998, Willey and van Riper 2000). The true efficiency of peregrine hacking programs is probably somewhere between best- and worst-case scenarios. For our study, the intermediate survival estimate to departure from the hacking area was 0.81. Powell et al. (2002) conducted a quantitative assessment of post-fledging survival in reintroduced peregrines and they estimated survival over a 10-wk post-fledging period was 0.89 in Iowa. Their success exceeded previous estimates and, to some extent, mirrored habitat-specific trends in success rates observed previously. For example, Barclay and Cade (1983) reported hacking success of 0.63, 0.79, and 0.83 for peregrines hacked on cliffs, towers, and urban sites, respectively. These early efforts involved learning through trial and error, but this general trend in habitat related success seems to hold. For example, although Powell et al. (2002) used a cliff, it was in a city park. Other studies have demonstrated high survival among peregrines in urban areas (Kauffman et al. 2003), possibly because of the extensive prey resources available in these areas or because many urban areas are largely devoid of predators. The intermediate survival rate among Peregrine Falcons we released approximated survival estimates based on observation in previous studies. Barclay and Cade (1983) suggested that raptor hacking programs generally achieve 75% success. Burnham et al. (1988) estimated that about 81% of hacked peregrines survived at least 3 wk.

Five peregrines died before dispersal, all at Daniel Boone. In each case we detected the transmitter in mortality mode near the hacking station, but we were able to recover only one of these carcasses. The causes of death remain unknown, but we speculate that the recovered carcass exhibited evidence of mammalian predation; this partially consumed carcass was found with primary feathers scattered in proximity to the carcass, no indication of plucking of secondary or downy feathers, and nearly complete consumption except for sacral and tarsal regions. Powell et al. (2002) suspected that one peregrine released in Iowa was killed by a mammalian predator, but all other mortality was associated with human-made structures such as a garbage dumpster (overcome by chlorine fumes), a utility pole (electrocution), and a livestock watering tank (drowning). Barclay and Cade (1983), Craig et al. (1988), and Walton et al. (1988) reported highest mortality due to predation by Great Horned Owls (*Bubo virginianus*) and Golden Eagles (*Aquila chrysaetos*). Despite the varied habitats and sources of mortality to which hacked peregrines have been exposed during the past three decades, the overall rate of mortality has been remarkably consistent among studies.

The shooting of one peregrine we released is unfortunate but the injury this peregrine sustained, a fractured ulna, is encountered with relative frequency by veterinarians and raptor rehabilitators (Deem et al. 1998, Wendell et al. 2002). Sweeney et al. (1997) reported that 71% of injured peregrines admitted to the University of Minnesota Raptor Center suffered fractures. Well-developed protocols for repair and rehabilitation of this type of injury exist.

No future peregrine hacking program in FWS Region four is scheduled. However, state agencies continue to monitor the status of peregrine populations in the southeast and nationwide as part of a cooperative federal and state effort pursuant to section 4(g)(1) of the Endangered Species Act (U.S Fish and Wildlife Service 2003). We have observed several peregrines that we hacked on cliffs in Kentucky return to the release region in subsequent years and defend territories. Given this and the estimated rate of survival among Peregrine Falcons released in Kentucky, we are hopeful that there will be an increase in territory occupancy in Kentucky and throughout the southeastern United States.

SUPERVIVENCIA, MORTALIDAD E INCIDENCIA DE ENFERMEDADES ENTRE LOS HALCONES *FALCO PEREGRINUS* EN KENTUCKY

RESUMEN.—Como parte de un programa para aumentar la recuperación del halcón *Falco peregrinus* en hábitats históricos del sur, reintrodujimos 33 halcones en acantilados de Kentucky. Monitoreamos la supervivencia, incidencia de enfermedades y las causas específicas de mortalidad durante un período de seis semanas posterior al abandono del nido por parte de los polluelos. Durante este programa, la supervivencia de los polluelos que abandonan el nido fue de 0.55, 0.81 y 0.85 para el peor, intermedio y mejor de los casos, respectivamente (intervalos de confianza del 95%: 0.38–0.72, 0.65–0.97 y 0.73–0.97, respectivamente). El riesgo de mortalidad no fue constante durante el periodo posterior al abandono del nido (χ^2 = 6.59, df = 1, P = 0.01); toda la mortalidad (N = 5) ocurrió durante los 14 días posteriores a la liberación.

[Traducción del equipo editorial]

ACKNOWLEDGMENTS

We thank L. Burford, T. Slone, and B. Balda of the Kentucky Department of Fish and Wildlife Resources, T. Carter, J. Larkin, J. Cox, and K. Anderson of The University of Kentucky College of Agriculture, K. Huie and R. Braun of the USDA Daniel Boone National Forest, and J. Bender and D. Skinner of the Kentucky State Nature Preserves Commission. This research (KAES 05-09-008) was connected with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director. All methods used during the program were approved by the University of Kentucky Institutional Animal Care and Use Committee (protocol No. 00504A2002).

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Received 4 March 2005; accepted 28 October 2006
Associate Editor: James W. Watson