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Cover Phograph: A banded peregrine falcon (Falco peregrinus) on a high-rise office building in Fayette County, Kentucky. Photograph by the Kentucky Department of Fish and Wildlife Resources. Used with permission.

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Lessons Learned from Managing Urban Peregrine Falcon Nests in Kentucky 1997–2021

Michael D. Patton[1*], Kate G. Slankard[1], and Kasia R. Bradley[1]

Abstract– The Kentucky Department of Fish and Wildlife Resources monitored Kentucky's nesting population of Peregrine Falcons 1997–2021. As part of these efforts, we monitored the productivity and survival of Peregrine Falcons hatched at urban nest sites using alphanumeric, colored leg bands, and used this data to identify which factors contributed most to the recruitment of young into the breeding population. Of the banded, wild-produced birds, 8% were re-sighted as breeders in the Eastern U.S.A and Canada. Parentage was important, and specifically, a few individual falcons produced more offspring that would go on to be breeders, than others. The percentage of falcons produced that became breeders did not differ significantly between natal sites on bridges and other urban locations. Breeding birds at recently discovered cliff nests included two adults that had been wild-produced at urban sites, indicating that continued management of urban sites may aid gradual expansion of the cliff-nesting peregrine population.

Introduction

The *Falco peregrinus anatum* Bonaparte (American Peregrine Falcon) experienced severe population decline during the mid-1900s. This decline was mostly attributable to eggshell thinning caused by the widespread use of the pesticide DDT. By the 1970s, populations east of the Mississippi River were extirpated (USFWS 2003). Restoration efforts in the 1970s–1990s, including the release of captive-bred birds into the wild and the outlawing of DDT in the US, led to a rebound in the nesting population which gained momentum in the Midwestern US in the 1990s (Redig et al. 2020). In Kentucky, the first nest in decades was established and documented on a bridge in downtown Louisville during 1997 (Burford 2001).

The American Peregrine Falcon was removed from the United States Fish and Wildlife Service endangered species list in 1999 (USFWS 1999). Nonetheless, due to local conservation concern, the Kentucky Department of Fish and Wildlife Resources (KDFWR) listed the Peregrine Falcon as a *Species of Greatest Conservation Need* in Kentucky's State Wildlife Action Plan (KDFWR 2013), and statewide restoration, management, and monitoring initiatives for the species continued to ensure Peregrine Falcons maintained healthy population levels in hopes that the species would re-colonize natural habitats.

Reintroduction efforts in Kentucky occurred from 1993–2003, and 115 captive-bred birds were released during this timeframe into urban areas and rural habitats near to cliffs (Dzialak et al. 2005). The KDFWR monitored the nesting population annually starting in 1997 and initiated a nestling banding program in 2001 (Burford 2001). Since then, Kentucky's nesting population has steadily increased, totaling 17 territorial pairs documented in 2021, with 14 nests on manmade structures (Patton and Bradley 2021). With 82% of Kentucky's nesting Peregrine Falcon population occurring on manmade structures, it is important to understand how to effectively manage these sites and determine if these nest sites contribute to the recolonization of nests at natural cliff sites.

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Several studies have investigated the nest success and/or productivity of urban peregrine nest sites in eastern North America (Gahbauer et al. 2015a, Kelly et al. 2018, Watts et al. 2018) and elsewhere (Altwegg et al. 2014, Kettel et al. 2019). Some of these studies demonstrated the benefit of nest boxes (Altwegg et al. 2014, Gahbauer et al. 2015a) and rescue of grounded fledglings (Gahbauer et al. 2015a) for increasing productivity and/or survival. Dispersal patterns in Peregrine Falcons produced in nest sites in the Eastern US have also been examined by several studies (Dennhardt and Wakamiya 2013, Faccio et al. 2013, and Katzner et al. 2012) with females typically dispersing farther than males to their first breeding location. The effect of natal site type on breeding site selection has also been a topic of study. Katzner et al. (2012) observed no preference for birds produced at one site type (e.g., bridge, building, cliff) to choose to breed at that or another site type. In contrast, Faccio et al. (2013) found that birds showed a tendency to nest on surfaces that were similar to those from which they fledged.

Past studies on Peregrine Falcons in Kentucky have focused on reintroduction efforts, home range, or mitigation techniques (Dzialak et al. 2007, Slankard et al. 2020, Taylor et al. 2020). Survival of captive-bred falcons during the post-fledging period in 1993–2003 in Kentucky was reported by Dzialak et al. (2007). Mitigation techniques for a pair of Peregrine Falcons nesting on a bridge during reconstruction were described in Slankard et al. (2020). While Dzialak et al. (2005) discussed the re-sighting of selected captive-bred individuals at nest sites, the overall recruitment of birds hacked during 1993–2003 into the nesting population has not been previously quantified in Kentucky.

Further, research on the long-term survival and recruitment of wild-produced young falcons into the breeding population, in relation to natal nest site management, is sparse. Tordoff et al. (2000) explored the relationship between the size of a brood from which individuals fledged to their probability of becoming a breeder in the Midwestern US and found no relation. Gahbauer et al. (2015b) found that wild-produced young were recruited to the breeding population almost twice as frequently as captive-bred birds in Ontario, Canada. Since urban nest sites inevitably require management, it is important to managers that these efforts contribute to the growth and stability of nesting populations.

In this study, we monitored the productivity and survival of Peregrine Falcons hatched at urban nest sites through the use of alphanumeric, colored leg bands. The objective of this study was to utilize Peregrine Falcon monitoring data, collected over 25 years in Kentucky, to guide the management of this species going forward. Specifically, we aimed to identify factors which contributed most to the recruitment of young into the breeding population. We further endeavored to evaluate the effects of other management considerations (e.g., disease, fledgling rescues, etc.) on the survival and recruitment of young falcons.

Methods

Field methods

In order to monitor as much of the Kentucky population as possible, we followed up on reports from the public to document new nest sites and conducted surveys for nesting at bridges in 2012 and 2018. We also conducted cliff surveys in areas with suitable cliff habitat (the Kentucky River Palisades, the Red River Gorge, and various locations in southeast KY) during 2008, 2011, 2012, and 2018.

To increase nest site availability and productivity, we installed 29 nest boxes at many urban locations throughout Kentucky between 1997 and 2021. Five nest boxes were installed on bridges, 5 at industrial facilities, 8 on buildings, and 11 at power plants. At accessible sites, we banded nestling Peregrine Falcons between the age of 21 and 28 days. We determined the sex of individuals using morphological measurements (Cade et al. 1996). Each Peregrine Falcon was fitted with a United States Geological Survey (USGS) leg band etched with a unique 9-digit number and a bi-colored band with a unique series of colors, letters, and numbers. All banding was permitted by the USGS Bird Banding Laboratory (BBL; Permit #23400). During the years 2005–2021, we tested 238 nestlings for *Trichomonas gallinae* Rivolta by use of a mouth swab, which we sent to the University of Tennessee at Knoxville for culture and/or PCR testing.

We re-sighted the leg bands of individuals through extended observations using a high-powered spotting scope, observer photography or automated photography (i.e., trail cameras at nest boxes). We monitored most nest sites during fledging and assisted grounded fledglings, when found or reported, by placing them back in the nest or at a nearby high location (e.g., rooftop).

Data assembly and statistical analysis

In order to gather data for this study, we queried the BBL for all band encounters of Peregrine Falcons banded in Kentucky (1997–2021). We also queried the Midwest Peregrine Society database (Midwest Peregrine Society 2022) for encounter and breeding location information, in addition to utilizing our own long-term database. One site along the Ohio-Kentucky state line at the Russell-Ironton Bridge was managed and banded by KDFWR until 2008 and then the Ohio Division of Wildlife took over management for the site after the nest moved to the Ohio side of the state line. We include data from this site prior to 2008 and exclude it from that point forward.

Birds were considered breeders if they were observed at breeding age at a nest where eggs, incubation or chicks were observed. Generalized linear mixed modeling was used to test the relationship between an individual being re-sighted as a breeder (binary response: breeder or not breeder) and explanatory variables of natal site type, mother, father, being rescued as a hatch year, and testing positive for *Trichomonas*. Akaike Information Criterion (AIC_c) model selection was used to select the best fitting model explaining the factors that led to a Peregrine Falcon becoming a breeder. Model averaging was used to obtain parameter estimates and 95% confidence intervals for multiple competing models ($\Delta AIC_c < 2.0$) using package *MuMIn* and function *model.avg* (Bartoń 2023). Peregrine Falcons that were captive-bred, banded as adults, or had unknown natal sites were removed from this portion of the analysis.

We calculated the number of years each breeding adult nested by counting the years including and between the first year the bird was re-sighted as a breeder and the last year. We categorized each nest site into 4 types: power plant, bridge, industrial facility, and city building. Due to a relatively small number of banded, breeding falcons, a Mann-Whitney U or Kruskal Wallis (when data was non-parametric) test was used to perform univariate analyses of each attribute to the mentioned responses. We used chi-square goodness-of-fit tests to compare the association between natal site type and eventual breeding site type, and between *Trichomonas* status and being re-sighted as a breeder. The program, R, was used to perform all statistical analyses (R Core Team 2022).

Results

One hundred fifteen captive-bred Peregrine Falcons were released in Kentucky during reintroduction efforts (1993–2003). Of these, 3.47% (4/115) became breeders in Kentucky and 1.7% (2/115) nested outside of the state. The last known, captive-bred breeding adult from Kentucky died in 2014 at the age of 17 after nesting at a bridge for many years.

During 1997–2021 there was a growing number of territories and active nests monitored throughout the state. In 2006 there were 9 territories with six nests, in 2014 there were 13 territories with 10 nests, and in 2021 there were 17 territories with 15 nests. During 1997–2021, 522 known Peregrine Falcon young were wild-produced in Kentucky nests and 67% (348/522) were banded. Of the banded birds, 17% (62/348) were encountered again by Dec 2021 and 8.0% (28/348) were re-sighted as breeders in the Eastern U.S.A and Canada. Six percent (21/348; 10 male and 11 female) were confirmed as breeders in Kentucky. Of all re-sighted falcons, 39% (24/62) were male and 61% (38/62) were female. Of the birds re-sighted as breeders, 57% (16/28) were male and 43% (12/28) were female.

There were 4 competing models to describe the relationship between banded falcons re-sighted as breeders, and the explanatory parameters (Table 1). Through model averaging, parentage, specifically the male falcon, 816-66344 (P=<0.001) and the natal site type, “industrial plants” (P=0.032), were found to be the significant coefficients of the competing models.

The male falcon, 816-66344, produced significantly more offspring that would go on to be breeders than any other male (N=10, P=<0.001; Fig. 1.) The female falcon, 1807-53995, produced significantly more breeding falcons than any other female (N=6, P=0.002; Fig. 2.). Statistically, the natal site type and eventual breeding site type were not significantly associated (P=0.137). The number of offspring produced by a breeding falcon was not associated with the breeding site type (P=0.888) or the natal site type (P=0.454). Specific nest sites did vary in the number of breeding birds that were produced and LG&E Trimble County produced more breeding Peregrine Falcons than other successful nest sites (Fig. 3). However, the percentage of falcons produced that became breeders did not differ between natal sites on bridges (pooled) and other urban locations (power plants,

Figure 1. Number of banded offspring per banded, breeding male. Numbers over each bar represent the number of years an individual nested. Banded offspring were more likely to become breeders if they were sired by 816-66344.

skyscrapers, industrial sites, pooled; P=0.08). The amount of banded, breeding falcons in Kentucky peaked in 2015 and steadily decreased after that, as the population of breeding birds in the state continued to rise (Fig. 4).

Of the 348 Peregrine Falcons that were banded, 64 (18.4%) were rescued shortly after fledging. Four of 28 (14.3%) falcons re-sighted as breeders were rescued as fledglings. Being rescued in the first year after hatching did not increase the likelihood of a falcon being re-sighted as a breeder (P=0.747), and there was no association with being rescued in the first year after hatching and the number of offspring produced (P=0.64). The number of years an adult bird nested was not associated with being rescued as a fledgling (P=0.947). Of the *Trichomonas* samples taken (N=238), 19 Peregrine Falcons tested positive. None of the 19 falcons that tested positive for *Trichomonas* were re-sighted as adults and there was no statistical association between the two variables (P=0.27).

Table 1. The 4 best fit models that describe which factors influence a Peregrine Falcon to become a breeding bird.

Models	AIC_c	AiC_cWt	Cum. Wt	LL
Father + *Trichomonas*	0	0.25	0.25	-78.30
Natal Site + *Trichomonas* + Father	0.58	0.19	0.44	-75.21
Father	0.61	0.18	0.62	-80.83
Natal Site + *Trichomonas*	1.92	0.10	0.72	-91.14

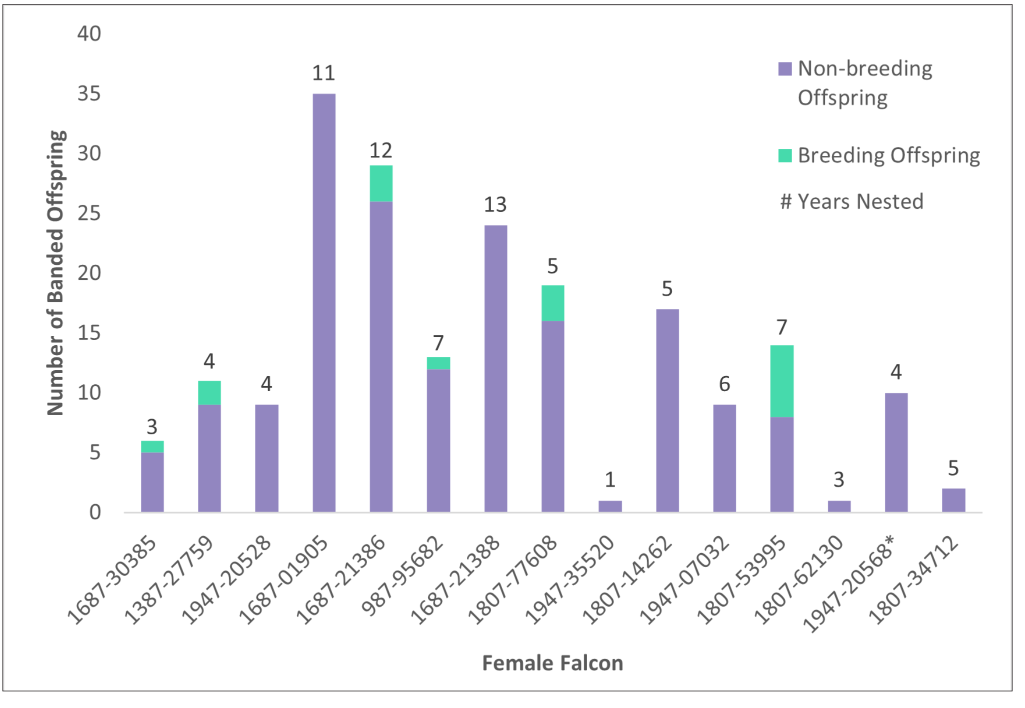

Figure 2. Number of banded offspring per banded, breeding female. Numbers over each bar represent the number of years each individual nested. The female falcon, 1807-53995, produced significantly more breeding offspring than any other banded female falcon.

Discussion

A significant goal in restoration efforts was to reestablish the species in historic cliff nesting habitats, and 2 nest sites on natural cliffs have been discovered in Kentucky in recent years. Breeding birds at these sites included un-banded birds, as well as a female that had been wild-produced at a bridge, and a male that was wild-produced at a power plant. Unfortunately, these cliffs are not accessible for nestling banding, but the presence of nesting adults which originated from human-made natal sites is encouraging that continued management of urban sites may lead to further expansion of the peregrine population to more cliff sites, albeit slowly.

Rangewide, the goal of returning this species to cliff habitats has been met with mixed success thus far (Watts et al. 2018). Use of human-made structures for nesting has become fairly widespread in urban areas, whereas the species only occasionally used these areas in North America prior to reintroduction (Faccio et al. 2013). The positive side to this result may be population resiliency to climate change. Sumasgutner et al. (2020), studied the breeding performance of Peregrine Falcons under varying weather conditions and found that falcons breeding in nest boxes were less sensitive to local weather changes than pairs using natural nest sites. Based on these results, they suggested that the urban peregrine population may better withstand climate change and extreme weather events.

Bridge sites can require considerable mitigation and coordination when it comes to bridge maintenance (Slankard et al. 2020). Thus, the contribution of these sites to the greater population is worth evaluation. We found no significant difference between bridge sites (pooled) and other site types (pooled) in the production of young that eventually became breeders (Fig. 4). Other studies have noted lower productivity at bridge sites when comparing to other urban site types (Gahbauer et al. 2015a), and fledging success can be low at bridge sites (Bell et al. 1996). However, our data shows these sites can produce young which contribute to the nesting population. A reduced number of young may benefit the fitness of those surviving to dispersal age at bridge sites due to increased parental care during the post-fledging window. We also installed nest boxes at selected bridges and rescued several young from bridge sites. Assistance with fledging may boost survival at these sites even though we didn’t find that fledging assistance increased the likelihood of a falcon being re-sighted as a breeder overall. Four of 28 (14.3%) falcons, re-sighted as breeders, were rescued as hatch years, and two of these were hatched at bridge sites. Thus, assisted fledging may be worthwhile, in the early phase of a species' recovery or when a significant portion of the population occurs on bridges.

None of the 19 falcons that tested positive for *Trichomonas* were re-sighted as adults, possibly indicating that exposure to this disease during the nestling phase may be catastrophic for survival. Exposure to trichomonads has been associated with consumption of pigeons and doves (*Columbiformes*) as prey, but may also be found in some passerines (Anderson et al. 2010, Samour and Naldo 2003). Urban peregrines are more likely to rely on pigeons for a large portion of their diet, and thus, this threat is probably more significant for urban nests.

Statistically, the natal site type and eventual breeding site type were not significantly associated in our study. Our results agreed with the findings of Katzner et al. (2012), which observed no preference for birds produced at one site type (e.g., bridge, building, cliff) to choose to breed at that or another site type. However, our results conflicted with Faccio et al. (2013), which found that birds showed a tendency to nest on surfaces that were similar (cliff vs. building) to those from which they fledged.

Due to accessibility and safety issues, we focused our banding efforts at sites where nests were in nest boxes. However, all sites were monitored for banded breeding adults, regardless of nest box status. Therefore, it's important to consider that our sample of banded birds from sites where the nest was not in a nest box was extremely small. In addition, while the natal site type, "industrial plants", was found to be important for falcons re-sighted as breeders, we think this was an effect of a small sample size of birds banded at this site type.

We did not find that the number of recruited offspring produced by a breeding falcon was associated with the breeding site type. However, we did observe differences between nesting sites and the number of breeding birds that were produced, with one site producing more than the others. This is further discussed below, but we surmise that local-scale site specifics (structure, predator abundance, etc.) are likely more important for survivability than the generalized type of the site (power plant vs. city building).

We found parentage to be important for future recruitment. It has been inferred in the past that individuals vary in productivity, which is correlated with life span (Tordoff and Redig 1997). In theory, longer lived birds should produce more offspring that are recruited into the nesting population. In addition, Peregrine Falcons that start breeding in their first year have been found to have greater lifetime reproductive success than birds entering the breeding pool as adults (Zabala and Zuberogoitia 2015). Vergara et al. (2010) found that

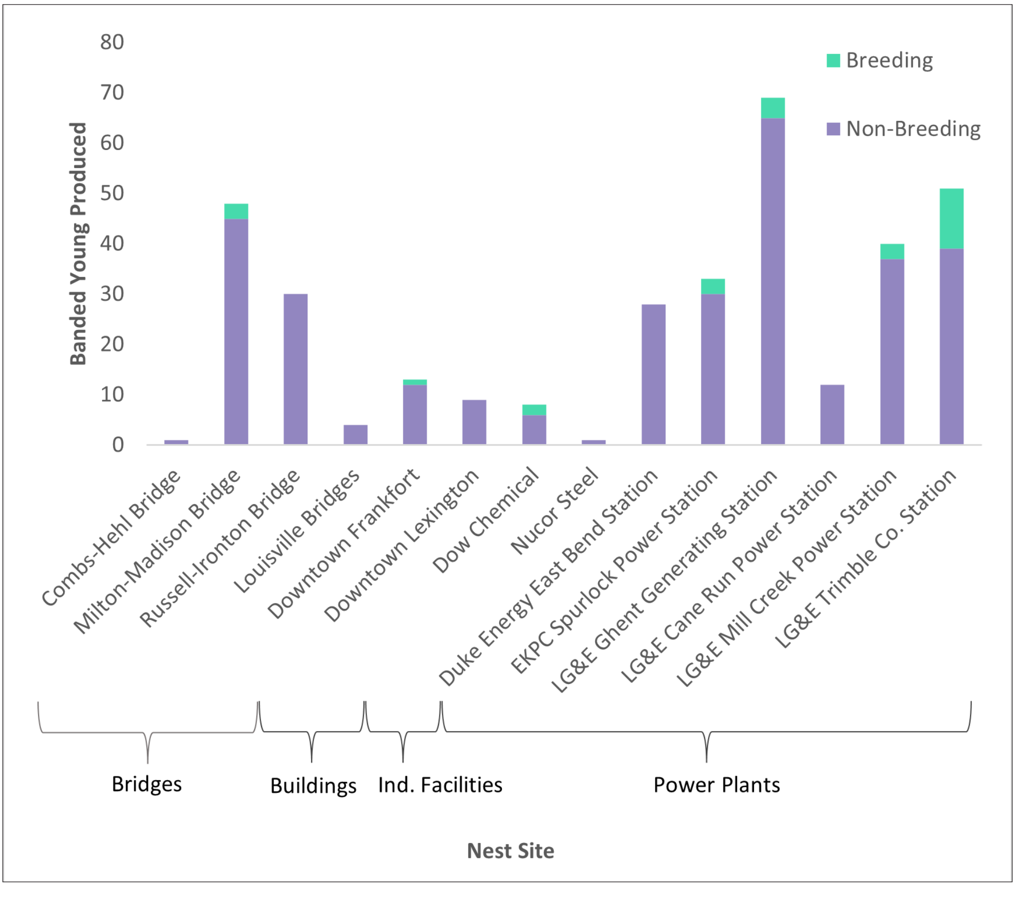

Figure 3. Young produced (wild) and banded at nest sites where young were banded. LG&E Trimble Co. Station produced more young later re-sighted as a breeder than any other site.

fledglings raised by higher-quality (as assessed using body condition and mass), Eurasian Kestrel (*Falco tinnunculus*) parents showed longer post-fledging dependence periods, a crucial stage for survival. The male (816-66344) that produced the most offspring which later became breeders (Fig. 1) was a captive-bred individual. His success was supported by an 8-year term of nesting at the same site and a long lifespan (14 years). However, many breeding males had longer nesting terms and did not produce as many young that were recruited into the nesting population (Fig. 1). The female falcon (1807-53995) that produced the most offspring, which later became breeders (Fig. 2), was a wild-produced individual that was the mate of (816-66344) for 7 years. Again, many breeding females had longer nesting terms and did not produce as many young that were recruited into the nesting population (Fig. 2). The nuances of this pair's particular nest site which did produce more recruited young than other sites were likely important, in addition to behavioral parental factors and a long nesting term for the pair (not just each individual). Although we did not find an association between the number of offspring produced by a breeding falcon and the breeding site type (power plant, bridge, etc.), it is apparent that some nest sites are superior, due to structural characteristics, than others. For instance, this pair's nest site was in a nest box in the side of a building at a power plant that had a lower rooftop directly in front of it. The simple availability of a safe location, off the ground, for fledging to occur may make this site superior for long term survivability. Further study would help to discern the importance of site-specific vs. parental factors in the production of recruited young.

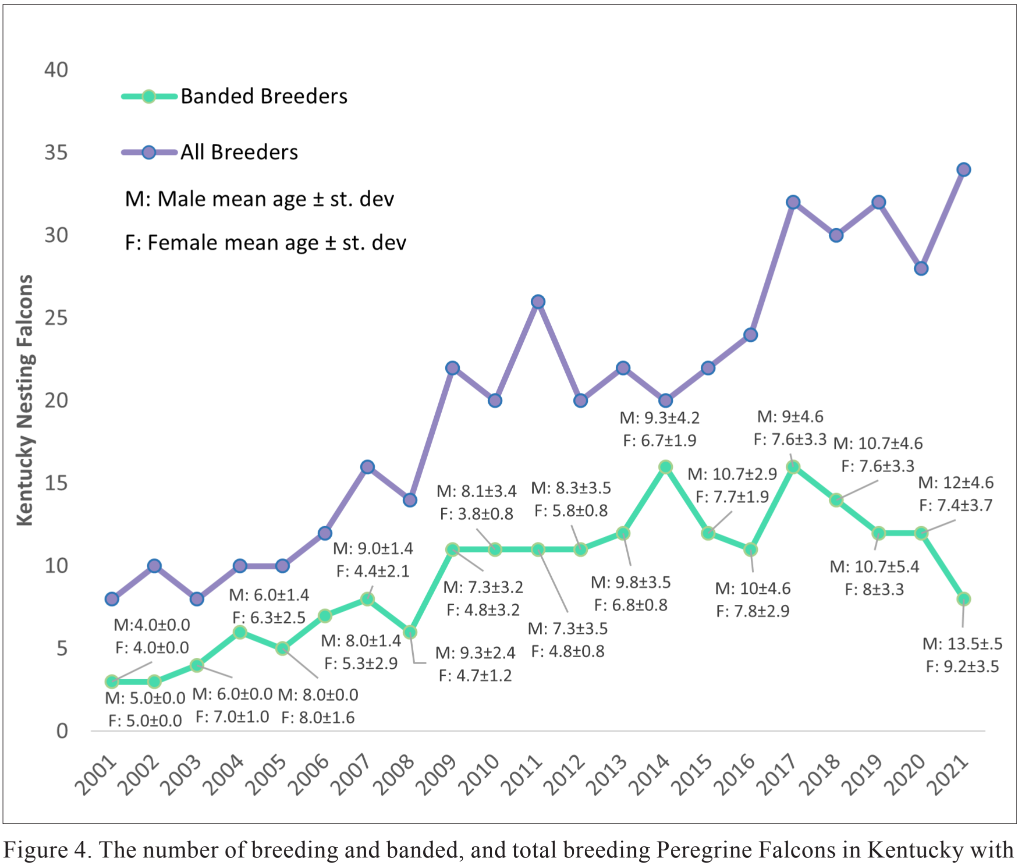

Figure 4. The number of breeding and banded, and total breeding Peregrine Falcons in Kentucky with mean age by sex during 2000–2021.

Our long-term monitoring efforts documented some fairly lengthy nesting terms for both male and female breeding falcons, with a few individuals of each sex nesting for over a decade (Figs. 1 and 2). Our anecdotal observations, satellite tracking and long-term monitoring efforts suggest Kentucky's nesting Peregrine Falcon population is non-migratory, residing at territories year-round (Taylor et al. 2020), and this may support longevity at nesting territories. Remaining at territories year-round circumvents migration, which is energetically expensive and can lead to greater mortality (Newton 2007; Franke et al. 2011).

Most of the expansion of the nesting population in recent years has been supported by nest box installations and partnerships with relevant utility companies, industrial facilities, and public agencies (i.e., transportation). In 2021, 63% (10/16) of Peregrine Falcon nests in Kentucky were in nest boxes and 59.4% (19/32) of young known to fledge came from these nests (Patton and Bradley 2021). The dependence of the population on partnerships and nest boxes will no doubt require management effort into the future to sustain the population and spur further growth into cliff habitats. Evaluations of monitoring data such as this can be useful for prioritizing these efforts going forward. When management resources are limited, it is reasonable to focus efforts on the sites which lead to the most eventual recruitment (Fig. 3).

As evaluations like these are not possible without banding efforts, some level of banding is required to make such assessments into the future, if desired. During 1997–2021, 67% (348/522) of known Peregrine Falcon young, wild-produced in Kentucky, were banded and 50.0% (21/42) of the banded falcons that nested in Kentucky were wild-produced here. Thus, band recovery ratios are no doubt affected by the amount of banding effort conducted elsewhere in the region. The number of banded, breeding birds in Kentucky peaked in 2014 and 2017 and steadily decreased after that (See Fig. 4), despite the number of nesting pairs continuing to increase. Federally coordinated post-delisting monitoring efforts ended in 2015, and banding efforts in some states ceased or were cut back at that point (Midwest Peregrine Society 2022). Thus, this pattern likely reflects a falling percentage of banded birds in the regional population.

The mean age of banded, breeding falcons has increased, especially over the past decade, indicating the banded, breeding population is aging (See Fig. 4). While this probably represents good longevity in breeding individuals, we may see a continued decline in the number of banded, breeding individuals in the coming years as these older birds are replaced and a smaller proportion of the nestlings are banded. While regional banding efforts are likely to continue to decrease going forward, the banding studies for Peregrine Falcons across the Eastern US during this species' recovery have demonstrated the dispersal and movement capabilities of these birds across state lines. Overall, these efforts emphasize the need to manage this population at the regional level to maintain long term stability.

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