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Research Article

Mitigation Translocation of Red-Tailed Hawks to Reduce Raptor–Aircraft Collisions

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ABSTRACT Translocation of problematic individual animals is commonly used to reduce human–wildlife conflicts, especially to reduce the presence or abundance of raptors within airport environments, where they pose a risk to safe aircraft operations. Although this method has strong public support, there have been no scientific evaluations of its efficacy or to determine which factors might influence the return of translocated birds to the airport. We conducted a study to determine which biological and logistical factors might influence the return of red-tailed hawks (*Buteo jamaicensis*) translocated from Chicago's O'Hare International Airport (ORD) during 2010–2013. We live-captured and translocated red-tailed hawks various distances from the ORD airfield and monitored for returning birds. We found the odds of hawk return increased by 2.36 (95% CI = 0.99–5.70) times for older birds (>1 yr of age) relative to younger birds (≤ 1 yr of age). Odds of hawk return went up 4.10 (95% CI = 0.75–22.2) times when translocations were conducted during the breeding season relative to the non-breeding season. The odds of hawk return increased 11.94 (95% CI = 3.29–43.38) times for each subsequent translocation event involving the same hawk. The cost of 1 translocation event to the release sites that were 81, 121, 181, and 204 km from ORD was \$213, \$284, \$362, and \$426, respectively. Management programs that use release sites 80 km from the airport minimize translocation events to include only younger birds during the non-breeding season, and undertake only 1 translocation event for an individual hawk would increase program efficacy and greatly reduce program implementation costs. The decision matrix regarding the use of a raptor trapping and translocation program involves a variety of biological, logistical, economic, and sociopolitical variables. This study represents an important first step in providing a scientific foundation for informing such management decisions. Published 2017.

KEY WORDS airport risk, bird strikes, *Buteo jamaicensis*, movements, raptors, red-tailed hawks, translocation.

The International Union for Conservation of Nature (IUCN) defined translocation as "the movement of living organisms from one area with release in another" (IUCN 1987). Most animal translocations are conducted with a purpose related to animal species conservation (Fischer and Lindenmayer 2000, Treves and Karanth 2003). However, translocation of problematic animals (i.e., mitigation translocations) represents another form of translocation with a goal of reducing human–animal conflicts (IUCN 2013). Mitigation translocation of problematic species (e.g., large carnivores, dangerous reptiles) is a common practice used in the management of human–wildlife conflicts (Fischer and Lindenmayer 2000, Massei et al. 2010, Sullivan et al. 2015).

Wildlife–aircraft collisions (wildlife strikes) pose a serious safety risk to aircraft. Wildlife strikes cost civil aviation ≥\$708 million annually in the United States (Dolbeer et al. 2015). Aircraft collisions with birds accounted for 97% of the reported strikes, whereas strikes with mammals and reptiles were 3% and <1%, respectively (Dolbeer et al. 2015). Raptors (e.g., hawks and owls) are one of the most frequently struck bird guilds within North America (Dolbeer et al. 2015). Raptor strikes pose a serious safety risk to civil (DeVault et al. 2011, 2016) and military aircraft (Zakrajsek and Bissonette 2005). Integrated wildlife damage management programs combine a variety of non-lethal and lethal management tools to reduce presence of raptors on airports (DeVault et al. 2013). Given high public interest, logistical and financial constraints, liability issues, and highly abundant populations of some species, managing raptors at airports presents some unique challenges.

Integrated wildlife damage management approaches are used to reduce the use of airfields by birds and mammals that pose hazards to aviation (Cleary and Dolbeer 2005). Non-lethal hazing (e.g., using pyrotechnics), use of anti-perching devices, habitat management, and lethal removal are commonly used

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components of these programs (Cleary and Dolbeer 2005, DeVault et al. 2013). Habitat management within airport environments is an important long-term component (Washburn and Seamans 2013). Frequently mowing the airfield, managing for a homogeneous grass type, and maintaining sparse vegetation are methods to reduce foraging opportunities for raptors within the airport environment because these factors affect prey abundance (DeVault and Washburn 2013). Pesticide applications are sometimes employed to reduce grasshopper (an attractant for American kestrels [*Falco sparverious*]) or small-mammal (an attractant for most species of raptors) abundance (Washburn et al. 2011, Witmer 2011) to indirectly reduce the presence of foraging raptors.

Mitigation translocation is a common practice used to reduce the hazards posed by raptors using airport environments (Cleary and Dolbeer 2005, Guerrant et al. 2013, Schafer and Washburn 2016). To our knowledge, there is no published information available regarding the efficacy of mitigation translocation for reducing raptor-aircraft collisions at airports. Consequently, scientific evaluations are needed because they are important for the development of effective raptor management methods within airport environments.

Red-tailed hawks (*Buteo jamaicensis*) are one of the most abundant and wide-spread raptors in North America. During 1966–2013, red-tailed hawk populations increased annually by 1.8% in the United States (Sauer et al. 2014). Red-tailed hawks are commonly involved in collisions with civilian and military aircraft and pose a notable risk to aviation safety (Zakrajsek and Bissonette 2005, Blackwell and Wright 2006, Dolbeer et al. 2015). We conducted a study to increase our understanding of mitigation translocations of problematic red-tailed hawks and the efficacy of such efforts in reducing the presence of this species within an airport environment. The objectives of our study were to determine return rates of red-tailed hawks following translocation from an airport, evaluate factors that might influence the return rates of translocated red-tailed hawks, and examine the economic costs of a red-tailed hawk translocation program.

STUDY AREA

We focused our study around Chicago's O'Hare International Airport (ORD) in Chicago, Illinois, USA. O'Hare International Airport (41°58′43″N, 87°54′17″W) is operated by the Chicago Department of Aviation and encompasses approximately 2,950 ha (Chicago Department of Aviation 2014). In 2010, there were over 67 million passengers and 882,612 aircraft operations at the airport, making ORD one of the largest and busiest civilian airports in the world (McMillen 2004, Airports Council International 2011).

The airport property comprises a variety of habitats, including pavement and buildings (1,281 ha), grasslands (1,375 ha), areas under construction (232 ha), and forest and shrublands (24.7 ha). Airfield grasslands (the dominant habitat type) comprises a mixture of grasses, forbs, and legumes, primarily tall fescue (*Schedonorus phoenix*) and clovers (*Trifolium* spp.). In addition, numerous water control structures (e.g., retention ponds) and drainage areas are distributed throughout the ORD airfield (Chicago Department of Aviation 2014). Mean annual precipitation at the study area is 930 mm/year with 56% typically falling as snow during October–April (Calsyn et al. 2012). Average daily temperatures are 22.2°C during summer and −4.1°C during winter. A variety of birds are found on the airport, although this faunal community is dominated by various raptors, gulls, and waterfowl (Guerrant et al. 2013, Chicago Department of Aviation 2014).

During 2007–2012, red-tailed hawks accounted for the majority of damaging wildlife strikes to aircraft at ORD and consequently their management is a major focus of the integrated wildlife damage management program at ORD (Guerrant et al. 2013). This program involves the implementation of several methods, including the planting of grasses that are less attractive to hazardous wildlife, mowing regimens to maintain airfield grassland habitats at short heights to reduce small-mammal numbers, modifying or removing perching sites, non-lethal harassment (e.g., pyrotechnics), live-capture and translocation, and lethal removal of wildlife that pose an immediate, direct hazard to aviation safety (DeVault et al. 2013).

METHODS

Capture and Handling

We conducted all raptor trapping, banding, and management activities at ORD under federal and state permits issued by the United States Fish and Wildlife Service and the Illinois Department of Natural Resources, respectively. During 2010–2013, we employed a variety of standard live-capture methods to capture red-tailed hawks that were presenting a hazard to aircraft at ORD. Swedish goshawk traps, pole traps, and bal-chatri traps were the primary tools used (Bub 1991, Bloom et al. 2007).

We assigned all live-captured red-tailed hawks to age classes based on plumage and eye coloration (Pyle 2008, Preston and Beane 2009). Younger birds were <1 year old at the time of capture. We assigned all other birds to the older age category (>1 yr old).

We banded all captured red-tailed hawks with a standard United States Geological Survey leg band and marked them with a pair of piercing patagial wing tags (1 on each wing; Varland et al. 2007). We made patagial wing tags (12 cm × 8 cm and teardrop in shape) from 610-g/m^2 polyvinyl chloride-coated material (Bondcote Corporation, Pulaski, VA, USA). We used green tags in 2010 and 2013, white tags in 2011, and orange tags in 2012. Each patagial tag had a 65-mm high 3-digit identification code in black or white letters.

We held all red-tailed hawks captured for <48 hours (from time of capture to release). We kept hawks in captivity under climate controlled conditions, in individual cages, and with minimal human disturbance.

Raptor Translocations and Monitoring

We assigned each bird to 1 of 4 pre-selected release locations using a stratified random selection process to ensure relatively equal sample sizes. The 4 release sites were located to the west

of the airport, within Illinois, and were 81–204 km (linear distance) from ORD. The release sites included Rock Cut State Park (42°21′18″N, 88°58′60″W; near Loves Park), Castle Rock State Park (41°58′40″N, 89°21′25″W; near Oregon), Morrison-Rockwood State Park (41°50′49″N, 89°57′55″W; near Morrison), and Witkowsky State Wildlife Area (42°18′28″N, 90°21′03″W; near Hanover) and were approximately 81 km, 121 km, 161 km, and 204 km, respectively, away from ORD. We chose these location distances because they could be logistically and financially feasible for use in an operational program. We categorized translocations from January through June as occurring during the breeding season, whereas translocations from July through December were in the non-breeding season (Preston and Beane 2009).

We conducted live-trapping activities for raptors, standard avian point-count surveys for hazardous wildlife (Clearly and Dolbeer 2005), and continual monitoring efforts during daily wildlife detection and hazard management activities on the airfield (Chicago Department of Aviation 2014) from August 2010 (the start of this study) to August 2014 (1 yr after the marking phase of the project ended). Wildlife Services airport biologists actively work on the ORD airfield from 0600 to 1800, Monday to Friday of each week. In addition, these biologists are staffed at ORD on weekends during spring and fall migration periods. We used lethal removal when it was necessary to mitigate emergency situations related to human health and safety following the repeated application of non-lethal methods (e.g., hazing with pyrotechnics).

Biologists examined all red-tailed hawks that were recaptured, involved in aircraft strikes, or observed on the ORD airfield for the presence of patagial wing tags and a metal leg band (if possible). They recorded the identity of all known individuals in addition to other pertinent information (e.g., date, time, location). We define a raptor return as any situation where an individual red-tailed hawk was resighted (e.g., visually observed) or recovered (e.g., re-captured, found dead) on ORD following a translocation event with that individual hawk.

We estimated the economic costs of translocation efforts from personnel and mileage costs directly associated with the translocation of red-tailed hawks. Personnel costs to translocate hawks were based on a mean standard salary and benefits rate of $34.39. We used an estimated mileage cost of $0.73/mile (American Automotive Association, Heathrow, FL, USA). In this evaluation, we did not take into account the costs to live-capture and handle the hawks, which included costs such as personnel (i.e., salaries and benefits), vehicle use (on the airfield), and equipment (e.g., traps, animal cages).

Statistical Analyses

Red-tailed hawk return (i.e., each translocation event) was a binary response variable, with 0 representing birds that were not resighted or recaptured on the airport following a translocation event and 1 representing those that returned to the airport at some point during the 4-year period. We developed a set of candidate models (involving all possible subsets of 5 factors and possible interactions) and then evaluated those models using Akaike's Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002). We used binomial logistic regression in program R Version 3.2.1 (R Core Team 2015) to model red-tailed hawk return as a function of 5 fixed factors: age (of the bird), season (breeding or non-breeding season), site (release site for translocation), trip (which translocation event it is for an individual bird; some hawks were translocated >1 time), and year (yr when translocation event occurred). We used model-averaging techniques using the R package AICcmodavg (Mazerolle 2015) to generate model-averaged parameter estimates for all models that had an $AIC_c < 2$ from the top model (Symonds and Moussalli 2011).

For each individual hawk that returned to ORD, we determined the days to return as the number of days from the translocation date to the first resight or recovery of the bird at ORD. We used 3-way analysis of variance (ANOVA; Zar 1996) to determine if there were differences in the days to return between younger and older hawks, birds translocated in the breeding season and non-breeding season, or among the 4 release sites. If a main effect was significant, we conducted means comparisons using Fisher's protected least significant squares (LSD) tests (Zar 1996). We considered differences significant at $P \leq 0.05$ and conducted all statistical analyses using SAS 9.1 (SAS Institute, Cary, NC, USA). These data are presented as mean (± 1 SE).

For red-tailed hawks that were first resighted at ORD and then (later) recaptured at the airport, the data were not normally distributed and we could not transform them satisfactorily. Thus, we compared the number of days until first resight of younger and older birds using Mann–Whitney *U*-tests and considered differences significant at $P \leq 0.05$ (Zar 1996). In addition, we used Mann–Whitney *U*-tests to compare the number of days until recapture for these same younger and older hawks. We used comparison of proportion tests (Zar 1996) to compare the proportion of returning hawks within the 2 age classes (younger and older) that were recaptured. In addition, we compared the proportion of returning hawks within the 2 age classes (younger and older) that were resighted (only) using comparison of proportion tests (Zar 1996).

RESULTS

Return Rates

We live-captured 577 individual red-tailed hawks and conducted 610 translocation events (some hawks were translocated >1 time) during 2010–2013. During the study, we conducted 159, 145, 151, and 155 hawk translocations to the Castle Rock, Morrison, Rock Cut, and Witkowski release sites, respectively. Overall, 168 translocations occurred during the breeding season and 442 translocations were conducted during the non-breeding season.

Approximately 82% of translocated red-tailed hawks ($n = 475$) were not observed or recovered at ORD post-release and these birds are considered to be of unknown fate. The other 102 individual red-tailed hawks returned to ORD

Table 1. Top 3 logistic regression models, ranked by Akaike's Information Criterion adjusted for small sample size (AIC_c), predicting red-tailed hawk returns following a translocation event ($n = 610$) from Chicago's O'Hare International Airport, Chicago, Illinois, 2010–2013.

Model	K[a]	LL[b]	AIC_c	ΔAIC_c[c]	w_i[d]	Cumulative w_i
Trip + age × season	5	−277.33	564.77	0.00	0.34	0.34
Age + trip × season	5	−277.49	565.09	0.32	0.29	0.63
Age + season + trip	4	−278.73	565.52	0.75	0.23	0.86
Null	1	−308.00	618.00	53.23	0.00	1.00

[a] Number of parameters in model.
[b] Log likelihood.
[c] Difference in AIC_c compared with lowest AIC_c model.
[d] Model weight.

and were resighted or recovered following ≥1 translocation events. Because we translocated some hawks more than once, there were 124 known fate outcomes from the returning individuals.

The top model with Akaike weight (w_i) = 0.34 included season (breeding vs. non-breeding), age (of the bird), and trip (no.) as important factors influencing hawk return rate (Table 1). The nearest 2 competing models, with w_i of 0.29 and 0.23, also included these same 3 factors, were also supported and were within <1 ΔAIC_c unit of the top model.

All 3 models indicated that older red-tailed hawks were more likely to return than younger birds (Table 2). Odds of hawk return increased by 2.36 (95% CI = 0.99–5.70) times for older birds relative to younger birds. Red-tailed hawks translocated during the breeding season were more likely to return compared to hawks translocated during the non-breeding season (Table 2). Odds of hawk return went up 4.10 (95% CI = 0.75–22.2) times in the breeding season relative to the non-breeding season. Red-tailed hawks were more likely to return to the airport following a second or third translocation event (of the same individual) compared to the birds with only 1 translocation event (Table 2). The odds of hawk return increased 11.94 (95% CI = 3.29–43.38) times for each subsequent translocation.

The days to return were similar between younger and older birds ($F_{1,108} = 0.06$, $P = 0.80$), hawks that were translocated during the breeding and non-breeding seasons ($F_{1,108} = 0.05$, $P = 0.82$), and birds relocated to different release sites ($F_{3,108} = 0.30$, $P = 0.82$; Table 3). In addition, there were no significant interactions among these factors (all $P \geq 0.18$).

Table 2. Model-averaged parameter estimates with unconditional standard errors (SE) and 95% confidence intervals (lower [LCL] and upper [UCL]) for red-tailed hawk returns following a translocation event ($n = 610$) from Chicago's O'Hare International Airport, Chicago, Illinois, 2010–2013.

Parameter	Estimate	SE	LCL	UCL
Intercept	−4.77	0.53	−5.81	−3.73
Age[a]	0.86	0.45	−0.01	1.74
Season[b]	1.41	0.86	−0.29	3.10
Trip	2.48	0.66	1.19	3.77

[a] The baseline for age was the younger birds. Thus, a positive parameter estimate older birds have a higher probability of return.
[b] The baseline for season was the non-breeding season. Thus, a positive parameter estimate indicates the breeding season is related with a higher probability of return.

Known Fate of Translocated Hawks

We reported known fate for 124 red-tailed hawks that returned to ORD following a translocation event. Upon their return, 2.4% of the hawks were involved in aircraft strikes, 21.8% were lethally removed (after being resighted on the ORD airfield), 30.6% were only resighted at the airport, 20.2% were recaptured (but not resighted prior to), and 25.0% were resighted and later recaptured at ORD. A higher ($Z = 4.56$, $P = 0.03$) proportion of younger birds returned to the airport and were consequently recaptured (56.3%) compared to the proportion of older birds that returned and were recaptured (25.0%). In contrast, the proportions of younger (27.5%) and older (31.8%) birds that returned to the airport and were only resighted was similar ($Z = 0.14$, $P = 0.71$).

There were 31 translocated hawks (25 younger, 6 older) that were resighted on the airfield and then (later) recaptured at ORD. The median number of days to resight for younger birds (54; first quartile = 35, third quartile = 137 days) was similar ($U = 1.63$, $P = 0.20$) to the median days to resight for older birds (22; 10, 81). However, younger birds were recaptured (50; 19, 193 days) in less time ($U = 5.07$, $P = 0.02$) than older birds (332; 151, 374 days).

Costs of Translocations

The cost of 1 translocation event to the release sites that were 81, 121, 181, and 204 km from ORD was \$213, \$284, \$362, and \$426, respectively. During the study, we made 22–25

Table 3. Days to return for red-tailed hawks following a translocation event from Chicago's O'Hare International Airport, Chicago, Illinois, 2010–2013.

Parameter	n	$\bar{x}$	SE	Min.	Max.
Age					
Younger[a]	80	124.0	21.0	3	1,143
Older[b]	44	144.0	26.6	6	725
Season					
Breeding[c]	49	129.1	24.3	4	709
Non-breeding[d]	75	132.3	22.2	3	1,143
Release site					
Rock Cut State Park	33	115.7	29.3	4	699
Castle Rock State Park	33	142.6	37.7	4	1,143
Morrison-Rockwood State Park	31	114.4	30.5	3	725
Witkowski State Wildlife Area	27	155.0	34.2	4	709

[a] Younger birds were ≤1 year of age.
[b] Older birds were >1 year of age
[c] Breeding season is January through June.
[d] Non-breeding season is July through December.

trips to each release site. However, given >1 red-tailed hawk could be translocated during an individual event (assuming they were available for transport), the actual total cost per bird was consequently less. On average, the cost per bird for translocation to the 81-km site was $44, to the 121-km site was $68, to the 181-km site was $85, and to the 204-km site was $95.

DISCUSSION

Homing behavior following a translocation action undertaken for a wildlife management need undermines the success of the intended action (Boschoff and Vernon 1988, Walsh and Whitehead 1993, Massei et al. 2010, Hinderle et al. 2015). To our knowledge, this is the first peer-reviewed study to evaluate return rates of raptors and the factors that influence the return probability of raptor return to an airport environment. Homing behavior (and thus return rates) of red-tailed hawks following a translocation event was influenced by several factors, including age of the hawk at the time of translocation, the season (breeding vs. non-breeding), and whether or not it was the first time an individual red-tailed hawk had been live-captured and translocated from the airport. Unexpectedly, we found no evidence that the distance from the airport a red-tailed hawk was taken influenced the probability of the bird's return to ORD. This finding is in contrast to the commonly held, yet previously unevaluated belief (within the airport wildlife management community) that the farther one translocates a raptor from an airport the lower the probability that the bird will return to that airport. We think that 200 km is likely not a substantial distance to overcome for a bird that can migrate up to 1,500 km (Preston and Beane 2009), especially when homing behavior is an important component of post-translocation movement patterns.

In general, juvenile raptors are more susceptible to live-trapping than are adult conspecifics (Bloom et al. 2007). This age-related difference might be further enhanced in red-tailed hawks following a translocation; we recaptured twice as many younger hawks compared to older red-tailed hawks during our study. This age-related difference in trapability and trap shyness could have implications for management of red-tailed hawk-aircraft collisions. Compared to their younger conspecifics, older red-tailed hawks that return to an airfield (following a translocation) could pose an increased risk of a collision with aircraft because they are more difficult to recapture and remove from the airfield.

The conservation or population status of an individual species strongly influences management decisions related to the management of human–raptor conflicts, especially at airports. A combination of lethal and non-lethal management tools is likely the most appropriate approach for highly abundant species, such as red-tailed hawks and American kestrels, that pose a hazard to human health and safety. In contrast, non-lethal methods (e.g., translocation) might be the only available option in regard to species with federal or state threatened or endangered status (e.g., short-eared owls [*Asio flammeus*], peregrine falcons [*Falco peregrinus*]).

Translocating raptors from an airport is a financially costly component of an airport wildlife damage management program. Overall, we estimated that the cost of translocating all of the red-tailed hawks during this study was approximately $44,500. However, the monetary costs of a raptor relocation program would be reduced if a slightly different management strategy were employed. For example, if all 610 hawk translocations were conducted at the shortest relocation distance from the airport (80 km) because relocation distance did not influence return rate to the airport in our study, the total cost would be roughly $25,850 (i.e., resulting in a cost savings of $17,650 or 40%). Further, if an aggressively different management plan would have been employed (i.e., translocating only younger red-tailed hawks during the fall and winter period, translocating all birds to the 80 km distance, and only translocating an individual hawk once), we estimate that the total cost of the portion of the translocation program would be approximately $7,965 (i.e., resulting in a cost savings of $36,532 or 73%). In addition, if the airport wildlife biologist was traveling away from the airport to translocate a raptor(s), he/she was not on the airfield addressing other wildlife-related safety issues and thus the risk of wildlife-aircraft collisions could be increased —possibly resulting in additional financial costs due to wildlife strikes that potentially could have been prevented by the biologist. We recommend airports and military airfields with existing raptor translocation plans conduct their own economic evaluations to examine the financial efficacy of those programs.

Management decisions on specific methods and practices to reduce the presence of raptors, such as red-tailed hawks, on

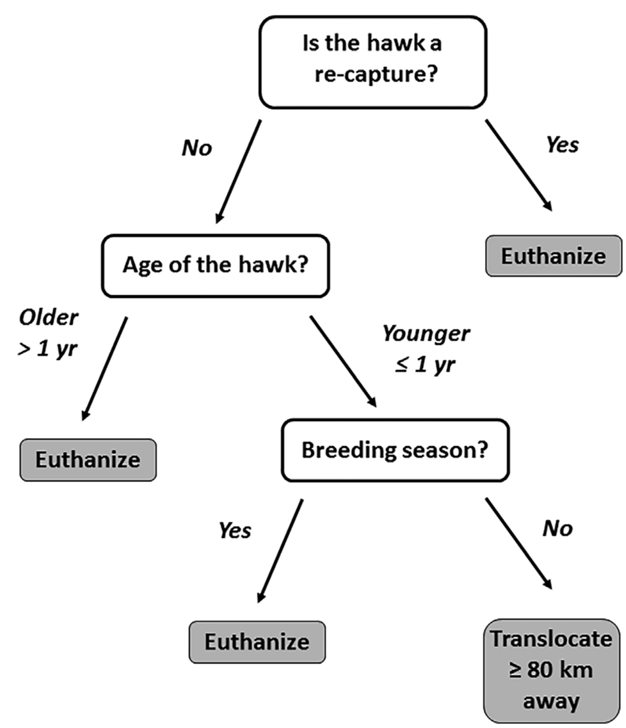

Figure 1. A decision matrix developed using the findings from our study to provide proposed guidance for managers and wildlife biologists. The decision matrix could be used when a red-tailed hawk is captured at an airport. Non-filled (white) boxes represent decision points, arrows represent answers, and filled (gray) boxes represent management actions.

airports involves a complex set of variables. A variety of ecological and sociopolitical factors, such as the biology of the species involved (this study), legal status of the species involved, direct economic costs of management actions, hidden logistical costs (Massei et al. 2010), personal and corporate liability of bird strikes (Dale 2009), and public perception of the management program in an increasingly social media-focused world (Cushing and Washburn 2014) might influence the selection of specific management actions taken. Although several of these factors are relatively straightforward, others are more complex when incorporating them into a decision matrix (Fig. 1).

This study represents an important first step in providing a scientific foundation for management efforts to reduce the risk of raptor–aircraft collisions. We suggest future research efforts should be focused on the efficacy of translocating red-tailed hawks in other landscapes or geographic regions, evaluating the use of translocation and consequently determining return rates of other raptor species, and gaining a better understanding of the homing behavior and movement patterns of raptors following a translocation event.

MANAGEMENT IMPLICATIONS

The components of an integrated wildlife damage management program to decrease the risk posed by raptors to safe aircraft operations can be influenced by many factors, some with a biological basis and some with a sociopolitical basis. Based on our study findings, we recommend that to minimize the return rate of translocated red-tailed hawks and consequently maximize the benefits of program resources, a civil airport or military airfield wildlife mitigation program should translocate only younger hawks during the non-breeding season, take those birds to a distance of at least 80 km from the airport, and translocate an individual hawk only once.

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