BioOne COMPLETE

# Detection Probability of Cliff-Nesting Raptors During Helicopter and Fixed-Wing Aircraft Surveys in Western Alaska

Authors: Booms, Travis L., Schempf, Philip F., McCaffery, Brian J., Lindberg, Mark S., and Fuller, Mark R.

Source: Journal of Raptor Research, 44(3) : 175-187

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/JRR-09-70.1

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

*J. Raptor Res.* 44(3):175–187
© 2010 The Raptor Research Foundation, Inc.

# DETECTION PROBABILITY OF CLIFF-NESTING RAPTORS DURING HELICOPTER AND FIXED-WING AIRCRAFT SURVEYS IN WESTERN ALASKA

TRAVIS L. BOOMS[1]
*University of Alaska Fairbanks, Department of Biology and Wildlife, 211 Irving I, Fairbanks, AK 99775 U.S.A.*
*and*
*University of Alaska Fairbanks, Institute of Arctic Biology, 902 North Koyukuk Drive, P.O. Box 757000, Fairbanks, AK 99775 U.S.A.*

PHILIP F. SCHEMPF
*U.S. Fish and Wildlife Service, Migratory Bird Management-Raptors, 3000 Vintage Boulevard, Suite 240, Juneau, AK 99801 U.S.A.*

BRIAN J. MCCAFFERY
*U.S. Fish and Wildlife Service, Yukon Delta National Wildlife Refuge, P.O Box 346, Bethel, AK 99559 U.S.A.*

MARK S. LINDBERG
*University of Alaska Fairbanks, Department of Biology and Wildlife and Institute of Arctic Biology, 211 Irving I, Fairbanks, AK 99775 U.S.A.*

MARK R. FULLER
*U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, 970 Lusk Street, Boise, ID 83706 U.S.A.*

ABSTRACT.—We conducted repeated aerial surveys for breeding cliff-nesting raptors on the Yukon Delta National Wildlife Refuge (YDNWR) in western Alaska to estimate detection probabilities of Gyrfalcons (*Falco rusticolus*), Golden Eagles (*Aquila chrysaetos*), Rough-legged Hawks (*Buteo lagopus*), and also Common Ravens (*Corvus corax*). Using the program PRESENCE, we modeled detection histories of each species based on single species occupancy modeling. We used different observers during four helicopter replicate surveys in the Kilbuck Mountains and five fixed-wing replicate surveys in the Ingakslugwat Hills near Bethel, AK. During helicopter surveys, Gyrfalcons had the highest detection probability estimate ($\hat{p}$; $\hat{p} = 0.79$; SE 0.05), followed by Golden Eagles ($\hat{p} = 0.68$; SE 0.05), Common Ravens ($\hat{p} = 0.45$; SE 0.17), and Rough-legged Hawks ($\hat{p} = 0.10$; SE 0.11). Detection probabilities from fixed-wing aircraft in the Ingakslugwat Hills were similar to those from the helicopter in the Kilbuck Mountains for Gyrfalcons and Golden Eagles, but were higher for Common Ravens ($\hat{p} = 0.85$; SE 0.06) and Rough-legged Hawks ($\hat{p} = 0.42$; SE 0.07). Fixed-wing aircraft provided detection probability estimates and SEs in the Ingakslugwat Hills similar to or better than those from helicopter surveys in the Kilbucks and should be considered for future cliff-nesting raptor surveys where safe, low-altitude flight is possible. Overall, detection probability varied by observer experience and in some cases, by study area/aircraft type.

KEY WORDS: Golden Eagle; *Aquila chrysaetos*; Gyrfalcon; *Falco rusticolus*; Rough-legged Hawk; *Buteo lagopus*; aerial survey; detection probability.

---

PROBABILIDAD DE DETECCIÓN DE AVES RAPACES QUE ANIDAN EN BARRANCOS DURANTE MUESTREOS DESDE HELICÓPTEROS Y AVIONES CON ALAS FIJAS EN EL OESTE DE ALASKA

RESUMEN.—Realizamos muestreos aéreos replicados de aves rapaces que anidan en barrancos en el Refugio Nacional de Vida Silvestre del Delta Yukon en el oeste de Alaska para determinar las probabilidades de

[1] Present address: Alaska Department of Fish and Game, Wildlife Diversity Program, 1300 College Road, Fairbanks, AK 99701; email address: travis.booms@alaska.gov



Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

detección de *Falco rusticolus*, *Aquila chrysaetos*, *Buteo lagopus* y de *Corvus corax*. Utilizando el programa PRESENCE, modelamos los históricos de detección de cada especie con base en modelos de ocupación por especie. Utilizamos observadores diferentes durante cuatro replicas de muestreo con helicóptero en las montañas Kilbuck y cinco muestreos desde un avión con alas fijas en las colinas Ingakslugwat cerca de Bethel, Alaska. Durante los muestreos desde helicóptero, *F. rustcolis* tuvo el mayor estimado de probabilidad de detección ($\hat{p}$; $\hat{p}$ = 0.79; EE 0.05), seguido por *A. chrysaetos* ($\hat{p}$ = 0.68; EE 0.05), *C. corax* ($\hat{p}$ = 0.45; EE 0.17) y *Buteo lagopus* ($\hat{p}$ = 0.10; EE 0.11). Las probabilidades de detección desde el avión con alas fijas en las colinas Ingakslugwat fueron similares a las estimadas a partir de muestreos desde helicópteros en las montañas Kilbuck para *F. rustcolis* y *A. chrysaetos*, pero fueron mayores para *C. corax* ($\hat{p}$ = 0.85; EE 0.06) y para *Buteo lagopus* ($\hat{p}$ = 0.42; EE 0.07). Los muestreos desde el avión con alas fijas realizados en las colinas Ingakslugwat proveyeron estimados y errores estándar de la probabilidad de detección similares o mejores que los estimados a partir de muestreos desde helicópteros en Kilbucks. Por esto, en lugares en que sea posible realizar vuelos seguros a baja altitud, los primeros debieran ser considerados en el futuro para muestreos de aves rapaces que anidan en barrancos. En general, las probabilidades de detección variaron con la experiencia del observador y en algunos casos con el área de estudio o tipo de aeronave.

[Traducción del equipo editorial]

Accounting for imperfect detection is an important component of rigorous wildlife surveys (Burnham 1981, Yoccoz et al. 2001, Pollock et al. 2002, Buckland 2006, Johnson 2008). Observers will miss some, possibly many animals during most surveys, and the detection probability likely varies with a number of factors such as weather, vegetation, animal color, and observer experience (Bowman and Schempf 1999, Rosenstock et al. 2002). Because detection probability can vary spatially and temporally, failing to estimate and account for variation in detection probability can bias inferences from counts (Link and Sauer 1998, Eberhardt et al. 1999, Thompson 2002).

Most survey protocols attempt to control for some of these factors by limiting surveys to similar, optimal conditions (e.g., conducted during good weather and with trained observers; Johnson 2008) or by integrating measures of some variables in analyses of counts. However, it is unreasonable to assume all or even most of the factors influencing bird detection probability can be measured accurately or controlled or accounted for by using covariates or constants (Nichols et al. 2000, Diefenbach et al. 2003). Results of counts that do not incorporate estimates of undetected but present animals rely on the assumption that detection probability is 1.0 and that it is constant among surveys (e.g., locations, time), or that the variability in detection probability is negligible compared to the size of potential change in counts (Johnson 2008). Assuming constant or near-constant detection probability is widely practiced, as evidenced in 95% of land bird surveys conducted between 1989 and 1998 (Rosenstock et al. 2002).

Imperfect detection is rarely accounted for in the majority of raptor survey methods (Andersen 2007), despite early examples with Ospreys (*Pandion haliaetus*) by Henny et al. (1977) and Bald Eagles (*Haliaeetus leucocephalus*) by Grier et al. (1981). This is particularly germane to raptor conservation because many species are uncommon, elusive, or threatened, making population monitoring difficult and the application of rigorous survey techniques all the more vital (McDonald 2004). There have been some other examples of applying detectability estimates to different types of surveys and to several raptor species (e.g., Geissler and Fuller 1986, Anthony et al. 1999, MacKenzie et al. 2003, Good et al. 2007, Henneman et al. 2007, Conway et al. 2008, Martin et al. 2009). However, we were unable to find published aerial detection probability estimates for cliff-nesting raptors during the breeding season even though aerial surveys are a commonly used technique for surveying raptors (Andersen 2007).

Therefore, we investigated the detection probability of cliff-nesting raptors during helicopter and fixed-wing surveys on the Yukon Delta National Wildlife Refuge (YDNWR) in May 2007. Our objectives were (1) to estimate the detection probabilities of Gyrfalcons (*Falco rusticolus*), Golden Eagles (*Aquila chrysaetos*), Rough-legged Hawks (*Buteo lagopus*), and Common Ravens (*Corvus corax*) during aerial surveys; (2) to determine if detection probabilities were influenced by observers; and (3) to evaluate the usefulness of fixed-wing aircraft in cliff-nesting raptor surveys.

## METHODS

We conducted aerial surveys for raptors in two study areas on the YDNWR in western Alaska, the Kilbuck Mountains and the Ingakslugwat Hills (hereafter called 'the Volcanoes') in May 2007.

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

The Kilbuck Mountains study area covers approximately 2000 km², is located at approximately 60°21′N, 160°W, and includes much of the Kisaralik and Kwethluk river watersheds. The area consists of large, open valleys and low mountains reaching 975 m. Our focus was on cliff nests, and most cliffs are typically discrete rock faces less than 300 m in length that occur along riverbanks or on valley hillsides. Many of the cliffs in the headwaters occur in narrow canyons where access by fixed-wing aircraft is difficult or not possible. The study area supports relatively high numbers of breeding Gyrfalcons and Golden Eagles; lower numbers of Rough-legged Hawks and Common Ravens are present. For simplicity, we considered the Common Raven a cliff-nesting raptor because of its similarity in breeding biology to raptors and the important role they play in creating and occupying cliff nests. The Kilbucks study area has been surveyed for cliff-nesting raptors on a mostly annual basis since 1977, and YDNWR maintains a GPS database of historical raptor nest sites.

The Volcanoes study area is dominated by small, inactive volcano craters typically less than 1 km wide and up to 200 m in height. The area is located at approximately 61°21′N, 164°W and covers 700 km². The Volcanoes study area is surrounded by the vast lowland deltas of the Yukon and Kuskowkim rivers, and provides the only cliff habitat for 90 km in any direction. The Volcanoes area was more conducive to fixed-wing aircraft surveys because the open landscape and low topography allowed for safer maneuvering among sites and lower flights over nesting habitat compared to the mountainous Kilbuck study area. The Volcanoes study area contains among the highest known nesting densities of Gyrfalcons (Booms et al. 2008) with a mean inter-nest distance of 4.7 km (B. McCaffery unpubl. data). Rough-legged Hawks and Common Ravens also nest in large numbers in the area; Golden Eagle nest density is low relative to the other species in Volcanoes, and to eagle densities in the Kilbucks (B. McCaffery unpubl. data). All species nest on the inner walls of the volcanoes, on small cliffs along the margins of lava flows, at isolated tors, and, with the exception of Golden Eagles and Rough-legged Hawks, occasionally in isolated stands of small balsam poplar (*Populus balsamifera*). BJM and YDNWR colleagues have surveyed cliff-nesting raptors in Volcanoes since 1988 and maintain a GPS database of historical nest sites.

**General Survey Design.** We followed the single-species, single-season study design for estimating detection and occupancy probability (MacKenzie et al. 2002, 2006). Gyrfalcons were our primary study species, and we designed the study to maximize the quality and quantity of data obtained for this species by surveying sites where Gyrfalcons had previously been observed breeding, by timing the surveys to coincide with the Gyrfalcon incubation period, and by using species-specific survey decision rules (see last paragraph below). We modeled data from all species simultaneously in our first modeling step to determine if partitioning data by species and study area was justified (see Model Development below). Based on results from these models, we modeled data on each species separately.

We conducted four and five aerial surveys (hereafter referred to as replicate surveys) of historical raptor nest sites in the Kilbuck Mountains and Volcanoes study areas, respectively, in May 2007. During each replicate survey, we collected detection data for each raptor species at historical nest sites; a bird was detected or no bird was detected. We then created detection histories for each species across all sites and sampling occasions (MacKenzie et al. 2006).

We used the following terms and definitions throughout: *Survey site*: site of a nest used previously by a raptor and marked with a GPS-obtained latitude and longitude accurate to within <20 m. All GPS locations were obtained in prior years from a helicopter hovering approximately 10–20 m from a nest. The site was considered occupied if a bird or an egg was detected within approximately 500 m of the nest and this area served as our sampling unit. When multiple historical nests were located on a single cliff, we used only one GPS location to locate the survey site. *Detection probability (p)*: the probability of a species being detected at a site given the site is occupied. *Occupancy* ($\psi$): the probability that the species of interest is present at a site during the survey period. A site was considered occupied if the species was detected there during any of the surveys; confirming breeding status was not necessary for us to consider a site occupied.

For a number of reasons we chose historical nests instead of random sites as the basis for our sample units and the starting point for each survey site. First, essentially all suitable nesting habitat in both studies areas had been previously surveyed and the resulting historical nests represented the majority of sites used by cliff-nesting raptors in the study areas. Second, we wanted to test this methodology and using historical nests provided us the largest sample

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

sizes. Third, using nest GPS locations from historical databases allowed us to easily standardize methodology and served as a useful starting point for searching the survey unit. Last, the four species used similar landscape features in our study areas, which allowed us to gather useful information on all species at historical nests.

One of four observers, with varying amounts of experience, conducted each replicate survey. Each observer had previously conducted 2, 10, 20, or 53 aerial surveys for cliff-nesting raptors from helicopters. For modeling purposes, we considered the two observers who had conducted 2 or 10 surveys as *inexperienced observers* and the two observers who had conducted 20 or 53 surveys as *experienced observers*.

Replicate surveys in each study area were flown by the same helicopter or fixed-wing pilot to maintain consistency. Pilots did not participate in the survey other than by flying aircraft and were asked not to aid observers in detecting birds to ensure objective, independent survey replicates. Each observer conducted one replicate survey in each study area (except TLB conducted two surveys in the Volcanoes, see below). To ensure surveys were independent, no survey results were shared among observers that might affect their search efforts.

To conduct a replicate survey, each observer used the same, predefined list of survey sites in a handheld GPS unit and used the GPS to navigate among sample units in the same order in each survey. All observers conducted replicate surveys according to the following decision rules: (1) if the GPS location was in front of a cliff, the survey team began surveying for raptors at the beginning of the cliff and made a slow pass in front of the entire cliff, passing through the GPS location; (2) if the GPS location was over a grove of trees, the team flew slightly to one side of the historical nest location; (3) if the GPS location was in a volcano crater, the team flew a straight line over the crater; (4) the team made three passes over all survey sites unless a Gyrfalcon was detected. Once a Gyrfalcon adult or egg was observed, no additional passes were made to minimize disturbance and reduce the likelihood of changing the birds' behavior in subsequent replicate surveys. If a species other than a Gyrfalcon was detected, the observer continued to survey the site until all three passes were completed. If an incubating Golden Eagle was detected, the observer continued to make passes in front of the site but remained at least 200 m (horizontal distance) from the nest to reduce disturbance to the bird. Observers recorded the presence or absence of each species at each survey site, the number of birds detected, the behavior of birds detected, the pass on which they were detected, and relevant breeding information (e.g., clutch size).

**Study Design by Study Area.** *Kilbuck Mountains.* All replicate surveys in the Kilbuck Mountains were conducted with a Robinson 44 helicopter because the topography precluded safe, effective surveying with a fixed-wing aircraft. Helicopter ground speed while surveying at sites was dictated by wind conditions but was always <20 km/hr and often <5 km/hr. Replicate surveys were conducted on different days between 7 and 13 May 2007. We surveyed 83 sites during each of the four replicate surveys; six sites were not surveyed during one replicate because of fuel limitations. We used observations from all 83 sites for analysis.

*Volcanoes.* Replicate surveys in the Volcanoes were conducted with an Aviat Husky fixed-wing aircraft because the open terrain and landcover was conducive to less expensive fixed-wing surveys. Airplane ground speed and altitude during surveys varied with wind conditions, but was generally 100 km/hr and 20–100 m above the terrain (Ritchie et al. 2003). Replicate surveys were conducted on different days between 5 and 14 May 2007. We surveyed 46 sites in each replicate survey. During one replicate, 28 sites were missed because an inexperienced observer became air sick. Therefore, TLB (experienced observer) conducted an additional replicate to ensure an adequate sample size; data from all 5 replicates and all 46 sites were analyzed.

**Statistical Analysis.** We used maximum likelihood estimation procedures in program PRESENCE 2.0 (Hines 2006) to obtain parameter estimates for $\psi$ and $p$ and followed recommendations by MacKenzie et al. (2002, 2006) and Burnham and Anderson (2002). We used model selection procedures (Burnham and Anderson 2002) to interpret Akaike's information criterion (AIC) values among competing models and report the parameter estimates and SEs from the model with the most AIC weight within each set of candidate models.

We used the ''assess model fit'' option in program PRESENCE for the most general model in each set of candidate models to calculate an overdispersion parameter estimate (c-hat) with 1000 parametric bootstraps. We did this because most count data from ecological studies are likely to be overdispersed, and statistical tests of ecological data

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

with small sample sizes such as ours have little power to detect overdispersion (Burnham and Anderson 2002). Therefore, in model comparisons, we used the conservative quasi-Akaike's information criterion (QAIC) that was corrected by c-hat to account for potential overdispersion. If c-hat $\leq 1$, we used c-hat = 1 to calculate QAIC (Burnham and Anderson 2002). Though overdispersion is unlikely to bias parameter estimates, it is likely to affect the SE of estimates. Therefore, we also adjusted the SEs of parameter estimates by multiplying the model-based SE by the square root of c-hat (Burnham and Anderson 2002). We report all parameter estimates followed by overdispersion-corrected SE in parentheses. Because our sample sizes were small when data were partitioned by species and study area, we used $QAIC_c$ to account for small sample sizes when making model comparisons.

Our methods included the following analytical assumptions (MacKenzie et al. 2006): (1) *Population of interest is closed during the sampling period.* This is a reasonable assumption for our work because we conducted all replicate surveys in the Kilbuck Mountains and Volcanoes within a 7- and 10-d period, respectively. However, we may have violated this assumption for Rough-legged Hawks because they may have been still searching for nest sites during our sampling period (see discussion below). We therefore interpreted results for this species in that context. (2) *The probability of occupancy is the same at all sites.* It is reasonable to expect that nest sites vary in quality and that higher quality sites might have a higher probability of occupancy. However, because historical data at our study sites were not collected with standardized efforts and methods that would have allowed us to assess occupancy probability at each site (largely because no detection probabilities could be estimated), we have no information with which to formally test this assumption. However, we believe potential variation in occupancy probability reflects natural variation that cannot be controlled or accounted for in many instances. The affect of violating this assumption is not well known, but it likely would have reduced the precision of our occupancy estimates (MacKenzie et al. 2006). Therefore, because violating this assumption would have only affected variation around occupancy estimates and because estimating occupancy was not a priority for this work anyway, we did not consider a potential violation of this assumption serious. (3) *Detection probability is the same at all sites.* Site-specific differences such as cliff color or complexity may influence detection probability during aerial raptor surveys to some unknown degree. Also, we do not know if detection probability of raptors at cliff sites is similar to that of raptors at poplar groves (Volcanoes). We did not include nest site type as a covariate in our models because there were relatively few tree nests. Violating this assumption would primarily result in negatively biased occupancy estimates and increased variation around detection probability estimates (MacKenzie et al. 2006). Ideally, we would have conducted this work at a larger number of sites with similar variations in physical characteristics (cliff color, degree of overhang, etc.) and then use these variables as covariates to model potential variation in detection probability. However, given typical limitations in survey funding, sample size, and natural, nearly continuous variation in many cliff characteristics, this approach was unrealistic for our study and most we can envision. Therefore, we consider any increased error part of the natural variation that would be difficult to account for in most cliff-nesting raptor surveys. Further, SEs around many of our detection probability estimates were reasonable and do not suggest that a potential violation of this assumption seriously compromised our results. (4) *The occupancy of a site is independent of the occupancy status of any other site.* This assumption could be violated in two ways when working with territorial birds such as raptors. First, a bird could defend a territory that included multiple nest substrates and prevent those sites from being occupied by conspecifics. However, we do not know the size or configuration of territories in our study areas. Also, we note that, at least in the Volcanoes, the proximity of nests suggests that the area a bird defends is small. Second, this assumption may also have been violated if birds were moving between historical nest locations and were detected at more than one site. This is unlikely, however, because raptors spend most of their time either hunting (in the case of the male) or occupying the nest cliff (Newton 1979). Violations of this assumption would have affected occupancy estimates. Future surveys that focus on estimating occupancy would need to ensure adequate and random spatial distribution of survey points to meet this assumption. Additionally, the potential effects of violating assumptions 2–4 on sampling variance estimates is at least partially accounted for by using c-hat to adjust variances.

**Model Development.** Though we suspected *a priori* that analyzing data from each species in each study area separately would be the most biologically

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Table 1. Model selection results from data pooled across species and area from aerial cliff-nesting raptor surveys on the Yukon Delta National Wildlife Refuge, Alaska, in 2007.

| MODEL | QAIC[a] | Δ QAIC[b] | QAIC WT[c] | NO. OF PARAMETERS |
|---|---|---|---|---|
| ψ(species + area) *p*(species) | 449.56 | 0.00 | 0.40 | 9 |
| ψ(species + area) *p*(species + area) | 449.97 | 0.40 | 0.32 | 10 |
| ψ(species + area) *p*(species + experience) | 451.43 | 1.87 | 0.16 | 10 |
| ψ(species + area) *p*(species + area + experience) | 451.92 | 2.36 | 0.12 | 11 |
| ψ(species + area) *p*(.) | 462.18 | 12.61 | 0.00 | 6 |
| ψ(species + area) *p*(area) | 463.95 | 14.39 | 0.00 | 7 |
| ψ(species + area) *p*(experience) | 464.18 | 14.61 | 0.00 | 7 |
| ψ(species + area) *p*(area + experience) | 465.93 | 16.37 | 0.00 | 8 |

[a] QAIC is the c-hat adjusted Akaike Information Criterion score to compensate for overdispersion, c-hat = 2.1.
[b] Δ QAIC is the difference between a model's QAIC score and the lowest QAIC score in the suite of models.
[c] QAIC wt is the relative weight of evidence for the model.

appropriate, we wanted to ensure that there was not more structure in the data than we suspected. Therefore, we combined all data across species and study areas and produced a candidate set of models using species, study area, observer experience, and all combinations of these covariates for *p*, and allowed ψ to vary by species and area (Table 1). We did not investigate ψ further because we considered it biologically unrealistic for occupancy not to vary by species and study area and because we were relatively uninterested in the complexity of ψ for this study. We then used standard model selection procedures to interpret ΔQAIC and QAIC weights among competing models and considered models with a ΔQAIC <2 as having substantial support (Burnham and Anderson 2002). Based on the resulting model QAIC weights, we then modeled data from each species in each study area separately and included observer experience as a covariate in all subsequent modeling.

We modeled each group of data with the following set of competing models:

ψ(.),*p*(.)—Constant occupancy and detection probability.
ψ(.),*p*(experience)—Constant occupancy but detection probability varied by observer experience.
ψ(.),*p*(survey)—Constant occupancy but detection probability varied by survey.

## RESULTS

When we combined all data, models with species as a covariate for *p*, including models that also had area, experience, or area and experience as covariates, received all of the QAIC weight (Table 1). Hence, partitioning data by species and study area for subsequent modeling was warranted, as was including experience as a covariate.

Detection probability estimates derived from models with the most support (Table 2) varied among species. Generally, Gyrfalcons were the most detectable, followed in order by Golden Eagles, Common Ravens, and Rough-legged Hawks (Table 3). However, detection probability of Rough-legged Hawks and Common Ravens differed greatly by study area/aircraft type. For example, Common Ravens, when surveyed by fixed-wing aircraft in the Volcanoes, were the most detectable of the four species at $\hat{p} = 0.85$ (SE 0.06). However, raven detection probability was much lower in the Kilbuck Mountains when surveyed by helicopters ($\hat{p} = 0.45$; SE 0.17), although this might have been an artifact of the low number of detections in the Kilbucks ($n = 3$).

Models with constant detection probability and those with observer experience as a covariate both received substantial support (Table 2). Models assuming constant detection probability always received more support, though the differences in $QAIC_c$ weights between observer experience and constant detection models within any suite of models varied from 0.01 to 0.47. Experienced observers had higher detection probability estimates than inexperienced observers for almost all species and study areas/aircraft types, though the differences were sometimes small (Table 3). There was relatively little support for different survey-specific detection probability for all species.

Though direct comparisons of detection probability estimates between aircraft type was not possi-

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Table 2. Model selection results from repeated aerial surveys of breeding cliff-nesting raptors on the Yukon Delta National Wildlife Refuge, Alaska, in 2007. Data from each species in each study area were modeled separately.

| MODEL | $QAIC_c$[a] | $\Delta$ $QAIC_c$[b] | $QAIC_c$ WT[c] | NUMBER OF PARAMETERS | C-HAT[d] |
|---|---|---|---|---|---|
| Gyrfalcon—Volcanoes | | | | | |
| $\psi(.),p(.)$ | 92.88 | 0.00 | 0.47 | 2 | 1 |
| $\psi(.),p$(exp) | 92.93 | 0.05 | 0.46 | 3 | 1 |
| $\psi(.),p$(survey) | 96.88 | 4.00 | 0.06 | 6 | 1 |
| Gyrfalcon—Kilbucks | | | | | |
| $\psi(.),p(.)$ | 129.57 | 0.00 | 0.53 | 2 | 1.1 |
| $\psi(.),p$(exp) | 130.04 | 0.47 | 0.42 | 3 | 1.1 |
| $\psi(.),p$(survey) | 134.04 | 4.47 | 0.06 | 5 | 1.1 |
| Golden Eagle—Volcanoes | | | | | |
| $\psi(.),p(.)$ | 54.14 | 0.00 | 0.65 | 2 | 1.2 |
| $\psi(.),p$(exp) | 56.20 | 2.06 | 0.23 | 3 | 1.2 |
| $\psi(.),p$(survey) | 57.64 | 3.50 | 0.11 | 6 | 1.2 |
| Golden Eagle—Kilbucks | | | | | |
| $\psi(.),p(.)$ | 182.87 | 0.00 | 0.49 | 2 | 1.1 |
| $\psi(.),p$(exp) | 183.04 | 0.17 | 0.45 | 3 | 1.1 |
| $\psi(.),p$(survey) | 186.82 | 3.95 | 0.07 | 5 | 1.1 |
| Rough-legged Hawk—Volcanoes | | | | | |
| $\psi(.),p(.)$ | 117.62 | 0.00 | 0.61 | 2 | 1.6 |
| $\psi(.),p$(exp) | 118.78 | 1.17 | 0.34 | 3 | 1.6 |
| $\psi(.),p$(survey) | 122.65 | 5.04 | 0.05 | 6 | 1.6 |
| Rough-legged Hawk—Kilbucks | | | | | |
| $\psi(.),p(.)$ | 56.69 | 0.00 | 0.65 | 2 | 1.4 |
| $\psi(.),p$(exp) | 58.30 | 1.62 | 0.29 | 3 | 1.4 |
| $\psi(.),p$(survey) | 61.29 | 4.60 | 0.06 | 5 | 1.4 |
| Common Raven—Volcanoes | | | | | |
| $\psi(.),p(.)$ | 75.18 | 0.00 | 0.73 | 2 | 1 |
| $\psi(.),p$(exp) | 77.20 | 2.02 | 0.26 | 3 | 1 |
| $\psi(.),p$(survey) | 83.74 | 8.56 | 0.02 | 6 | 1 |
| Common Raven—Kilbucks | | | | | |
| $\psi(.),p(.)$ | 46.10 | 0.00 | 0.71 | 2 | 1 |
| $\psi(.),p$(exp) | 48.25 | 2.15 | 0.24 | 3 | 1 |
| $\psi(.),p$(survey) | 51.50 | 5.40 | 0.05 | 5 | 1 |

[a] $QAIC_c$ is the Akaike Information Criterion corrected for small sample size and for potential overdispersion using c-hat.
[b] $\Delta QAIC_c$ is the difference between a model's QAICc score and the lowest QAICc value in the suite of models.
[c] $QAIC_c$ wt is the relative weight of evidence for the model.
[d] C-hat estimates <1 were set equal to 1.

ble because they were confounded by study area, fixed-wing aircraft in the Volcanoes provided estimates of detection probability for Gyrfalcons and Golden Eagles similar to those from helicopter surveys in the Kilbucks (Table 3). Detection probability estimates for Common Ravens and Rough-legged Hawks however, were higher in fixed-wing surveys. We suspect this may be at least partly due to the low number of detections for these species in the Kilbucks helicopter surveys, differences between study areas, and, for Rough-legged Hawks, possibly due to a violation of the assumption of population closure (see discussion below).

## DISCUSSION

Our results indicated that detection probability for raptors at historical nest sites during helicopter and fixed-wing surveys in western Alaska differed by

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Table 3. Detectability estimates for each species by study area and aircraft type on the Yukon Delta National Wildlife Refuge, Alaska, in 2007. Detectability estimates for experienced and inexperienced observers provided from models assuming detectability varied by observer experience (p(experience)).

| SPECIES | STUDY AREA/AIRCRAFT | MODEL | DETECTABILITY ($\hat{p}$) | EXPERIENCED OBSERVER DETECTABILITY ($\hat{p}$) | INEXPERIENCED OBSERVER DETECTABILITY ($\hat{p}$) | TOTAL NUMBER OF SITES SPECIES WAS DETECTED |
|---|---|---|---|---|---|---|
| Gyrfalcon | Kilbucks—Helicopter | $\psi(.)\ p(.)$ | 0.79 (0.05)[a] | — | — | 14 |
| | | $\psi(.)\ p$(experience) | — | 0.87 (0.06) | 0.72 (0.08) | 14 |
| | Volcanoes—Fixed-wing | $\psi(.)\ p(.)$ | 0.78 (0.07) | — | — | 9 |
| | | $\psi(.)\ p$(experience) | — | 0.85 (0.07) | 0.64 (0.13) | 9 |
| Golden Eagle | Kilbucks—Helicopter | $\psi(.)\ p(.)$ | 0.68 (0.05) | — | — | 20 |
| | | $\psi(.)\ p$(experience) | — | 0.75 (0.08) | 0.60 (0.09) | 20 |
| | Volcanoes—Fixed-wing | $\psi(.)\ p(.)$ | 0.69 (0.10) | — | — | 5 |
| | | $\psi(.)\ p$(experience) | — | 0.73 (0.13) | 0.62 (0.18) | 5 |
| Rough-legged Hawk | Kilbucks—Helicopter | $\psi(.)\ p(.)$ | 0.1 (0.11) | — | — | 5 |
| | | $\psi(.)\ p$(experience) | — | 0.15 (0.16) | 0.08 (0.10) | 5 |
| | Volcanoes—Fixed-wing | $\psi(.)\ p(.)$ | 0.42 (0.07) | — | — | 20 |
| | | $\psi(.)\ p$(experience) | — | 0.53 (0.12) | 0.40 (0.08) | 20 |
| Common Raven | Kilbucks—Helicopter | $\psi(.)\ p(.)$ | 0.45 (0.17) | — | — | 3 |
| | | $\psi(.)\ p$(experience) | — | 0.45 (0.21) | 0.45 (0.22) | 3 |
| | Volcanoes—Fixed-wing | $\psi(.)\ p(.)$ | 0.85 (0.06) | — | — | 8 |
| | | $\psi(.)\ p$(experience) | — | 0.90 (0.09) | 0.83 (0.08) | 8 |

[a] SE in parentheses corrected by multiplying model-based SEs by square root of c-hat for each model set (Table 2).

species, study area, aircraft, and observer experience. Commonly, survey results are used to compare the occurrence of animals among geographic areas or through time for the purpose of monitoring status. Our results demonstrated that several factors were associated with differences in the probability of observing raptors among surveys and thus are important for interpreting and comparing results.

**Species Differences.** Gyrfalcons were the focal species for these surveys and the timing, design, and execution of the surveys were tailored to maximize the likelihood of detecting Gyrfalcons. It is therefore unsurprising that Gyrfalcons had some of the highest detection probability estimates ($\hat{p} = 0.78$ and 0.79). Had replicate surveys been conducted later in the breeding season, detection probability for other species might have been higher, especially in the case of Rough-legged Hawks, which breed later than Gyrfalcons and Golden Eagles. Also, because of species-specific survey decision rules, we conducted more survey passes when Gyrfalcons were not observed. These additional passes could have influenced differences among species detection probabilities if birds changed behavior during the survey season because of repeated disruptions (passes). Last, we emphasize that the detection probability estimates presented here are likely minimum estimates because the pilot was not allowed to participate in the survey. We expect that detection probability would have been slightly higher had the pilots participated as is typically done during aerial surveys.

Surprisingly, our detection probability estimates for Rough-legged Hawks were lower than those for Golden Eagles. We expected Rough-legged Hawks to be more detectable than eagles because of the hawks' propensity to flush when disturbed and because of their contrasting wing and tail plumage patterns. We suspect that our estimates for Rough-legged Hawk detectability are biased low because their populations may not have been closed during our survey period and therefore violated a critical assumption of occupancy modeling. Two lines of reasoning support this hypothesis. First, Rough-legged Hawks are the last of the four species to initiate nesting on our study areas (T. Booms and B. McCaffery unpubl. data). We failed to detect evidence of breeding (eggs or young) during many of our sightings of Rough-legged Hawks, even though we commonly detected evidence of breeding for the other species. Second, the number of sites at which Rough-legged Hawks were detected generally increased during our survey period in the Volcanoes and Kilbucks. Total counts of sites at which Rough-legged Hawks were detected during each replicate from earliest to latest calendar date were 9, 6, 10, and 14 in the Volcanoes (excluding the incomplete survey) and 1, 1, 2, and 4 in the Kilbucks. Based on these counts, Rough-legged Hawk occupancy appeared to increase during the survey period, probably because they were still in the process of choosing nest sites and initiating nesting. This likely caused a closure assumption violation and resulted in biased detection probability estimates for Rough-legged Hawks.

We attributed the high detection probability of ravens in the Volcanoes ($\hat{p} = 0.85$) to their conspicuous black plumage and use of nests in small, isolated, easily surveyed poplar stands. Additionally, Common Ravens in the Volcanoes had a nesting phenology very similar to Gyrfalcons and the timing of the surveys was probably optimal for detecting ravens. We are unsure why detection probability of ravens was relatively low in the Kilbucks, but this was perhaps a function of low occupancy (estimated 0.04) or more cryptic nest site placement than in the Volcanoes.

Except for Martin et al. (2009), we are unaware of detection probability estimates for these species or for cliff-nesting raptors in general during breeding-season surveys. For Golden Eagles breeding in Denali National Park, Alaska, Martin et al. (2009) estimated detection probabilities during a combination of repeated helicopter and ground-based surveys varied from 0.90–1.0. These estimates are higher than ours and the difference is most likely explained by their use of ground-based work to complement aerial surveys and by differences in study area and observer experience. We found no other estimates with which to compare ours or to investigate potential spatial, methodological, or temporal differences. This highlights a significant deficiency in and obstacle to the study and conservation of birds of prey (Anthony et al. 1999).

There are published studies that estimated detection probability of eagles, hawks, or owls during other types of surveys. For example, detection probability estimates of Red-shouldered Hawks (*Buteo lineatus*) varied from 0.11 to 0.45 among four study areas (Iverson and Fuller 1991). Estimates for Spotted Owls (*Strix occidentalis*) during ground surveys of historical nesting areas ranged from 0.53–0.76, and varied widely, both temporally and spatially (Olson et al. 2005). Wintle et al. (2005) found that ground

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

surveys for the Powerful Owl (*Ninox strenua*) and Sooty Owl (*Tyto tenebricosa*) in Australia produced low estimates of detection probability ($\hat{p}$ = 0.13 and 0.26, respectively). Bald Eagle sightability estimates during fixed-wing aerial surveys in two areas in Oregon were 0.64 and 0.35, and sightability was lower during aerial surveys than during ground surveys (Anthony et al. 1999). Bowman and Schempf (1999) estimated detection probabilities for adult Bald Eagles at $\hat{p}$ = 0.79 and for immature eagles at $\hat{p}$ = 0.51 from fixed-wing aerial surveys during the breeding season in south-central Alaska. Good et al. (2007) conducted fixed-wing aerial line-transect surveys across the western United States for Golden Eagles after the breeding season and estimated the detection probability of perched eagles at $\hat{p}$ = 0.29 and flying groups of eagles at $\hat{p}$ = 0.55, though estimates varied with detection distance. Finally, using broadcast call surveys and program PRESENCE, Henneman et al. (2007) found Red-shouldered Hawks had an average detection probability of $\hat{p}$ = 0.38 across four years of breeding surveys and annual estimates varied from $\hat{p}$ = 0.28 to $\hat{p}$ = 0.54. Collectively, these studies highlight the need to account for detection probability during raptor surveys because probability of detection can vary widely by species, area, survey type, time, and other factors. It is possible that detection probabilities for cliff-nesting raptors may not change significantly across years if methods, good weather, and observers remain the same. Investigating this with additional work in our and other study areas would help identify the best balance between the need to account for detection probability and survey costs. Our findings with cliff-nesting raptors in western Alaska further support the need for more research on, and applications of, detection probability estimation in raptor surveys.

**Observer Experience Differences.** Although often only marginally better than competing models, models assuming constant detection probability received the most support. Models with observer experience as a covariate also received substantial and sometimes very similar amounts of support. Whether looking at the cumulative data set (Table 1) or individual species by study area data sets (Table 2), the majority of models that included observer experience as a covariate for detection probability received substantial support and sometimes nearly the same amount of support as the top model assuming constant detection probability. We interpret these results, along with the differences in experience-specific parameter estimates (Table 3), as indicating that observer experience generally influenced detection probability and this conclusion has been well documented in other bird surveys (Diefenbach et al. 2003).

However, observer experience may influence detection probability to a greater or lesser extent in different species. For example, Common Raven models that included observer experience as a covariate for detection probability did not receive substantial support (ΔQAICc = 2.02 and 2.15) while those for Gyrfalcons did (ΔQAICc = 0.05 and 0.45). Also, the difference in detection probability estimates between experienced and inexperienced observers was the least for Common Ravens (0.0 in helicopters and 0.07 in fixed-wing) and the most for Gyrfalcons (0.15 in helicopters and 0.21 in fixed-wing). We concluded that Common Raven detection probabilities were the least affected by observer experience while those of Gyrfalcons were the most affected. Therefore, not only did detection probabilities differ among species, but the degree to which observer experience influenced detection probability differed among species.

**Study Area/Aircraft Differences.** We did not conduct helicopter surveys in the Volcanoes or fixed-wing surveys in the Kilbucks because of budgetary and logistical considerations. Therefore, direct comparisons of detection probability by aircraft type or between regions were not possible because aircraft type and study area were confounded. We conclude, however, that in the Volcanoes study area, fixed-wing aircraft generally provided detection probability estimates and SEs that were similar to or higher and more precise than those generated by helicopters in a different area (Table 3). Furthermore, fixed-wing surveys were much less expensive than helicopter surveys ($100/hr vs. $700/hr). Thus, we encourage the evaluation of the use of fixed-wing surveys in long-term raptor monitoring programs for estimating occupancy. Counting eggs or young is difficult from fixed-wing aircraft (T. Booms and B. McCaffery unpubl. data) and fixed-wing aircraft might be less suitable for surveying very rugged, mountainous terrain for obvious safety reasons. Our work demonstrates that at least for some applications, fixed-wing aircraft are a suitable survey platform for cliff-nesting raptor surveys.

**Implications for Future Surveys.** Conducting two repeat helicopter surveys may be prohibitively expensive for YDNWR and other organizations interested in population monitoring. If so, conducting

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

repeat visits at only a subset of survey points may be possible and could allow detection probability to be estimated. In areas that allow for safe maneuvering and low flight in a fixed-wing aircraft, planes may provide a more cost-effective option that would enable the YDNWR and others to fund future surveys on a long-term basis while still surveying in a rigorous, defensible manner.

In some situations, using a double-observer approach during a single survey as was done by Anthony et al. (1999) and Bowman and Schempf (1999) could be less expensive than replicated surveys. Unfortunately, helicopters and tandem-seat airplanes best suited for cliff-nesting raptor surveys do not provide multiple observers the same field of view and therefore are problematic for double-observer methods. Conducting repeated surveys was the only tenable option for estimating detection probability using the types of aircrafts most suited to cliff-nesting raptor surveys. Our results and those of others show that it is scientifically justified to expend the resources to account for imperfect detection during raptor surveys.

The YDNWR contains expanses of landscape in which cliff-nesting raptors do not occur, thus a randomized survey design that encompassed all of the refuge would have been impractical to implement to cover enough nesting habitat to provide counts large enough to be useful. In our study, SEs for species detected at $\leq 5$ sites were large. A design based on historical nest locations was suitable for our objectives as we described in the Methods section. However, survey objectives commonly require estimates that are representative of all nest sites in the area being sampled, not only information about historical nests. Information based only on historical nests is incomplete because not all nests have been discovered, some nests are abandoned, and new nests are established. Survey design also has important ramifications when distinguishing between the proportion of sites occupied and the probability of occupancy ($\psi$) (MacKenzie et al. 2006). Nevertheless, information about historical nesting, such as nest substrate, surrounding terrain, etc., can be used to develop a suitable design. An example of such a design is the dual frame method (Haines and Pollock 1998) comprising a list frame of all known nests in the study area and an area frame that delineates plots in which additional surveys for nests are conducted. The sample information from both frames is combined to estimate the number of nests in the study area. Millar et al. (2007) applied the Haines and Pollock (1998) approach in a draft monitoring plan for Bald Eagles that included an estimate of detection probability using the double-observer method described by Nichols et al. (2000).

Our results have important implications for raptor nest site surveys. First, we demonstrated that not all cliff-nesting raptors are detected during a survey and that detection probability was associated with a number of factors. Our results indicate the importance of estimating detection probability in future raptor surveys to allow for robust, reliable, scientific population monitoring across time and space. Second, we provided the first estimates of detection probability during aerial surveys for these four species of cliff-nesting birds during the breeding season. These estimates can be used to guide the design of future surveys so that others can more easily estimate detection probabilities of raptors in other places and times. Although our estimates cannot be generalized across time or space, replicating this study at this and other study sites would allow researchers to assess the degree of generality among species-specific estimates of detection probability. If similar detection probabilities are repeatedly documented, there might be a basis for estimating this parameter less often than during each survey period. Such a finding also could increase our ability to interpret trends in survey data. Third, we demonstrated that accounting for imperfect detection probability was possible even in remote, logistically difficult study areas; doing so is likely feasible in other challenging study areas. Fourth, fixed-wing aircraft were an effective, comparatively inexpensive survey platform in a study area that allowed for safe, very low altitude flying; they deserve additional consideration by others planning aerial raptor surveys in areas that allow use of fixed-wing aircraft.

## ACKNOWLEDGMENTS

This work was funded by the U.S. Fish and Wildlife Service Office of Migratory Birds Raptor Management Office. TLB was supported by a U.S. Environmental Protection Agency (EPA) Science to Achieve Results Graduate Fellowship, a University of Alaska Fairbanks Thesis Completion Fellowship, and the Alaska Department of Fish and Game Wildlife Diversity Program while conducting portions of this work. The EPA has not officially endorsed this publication and the views expressed herein may not reflect the views of the EPA. We thank F. Broerman and J. Spice for conducting replicate surveys and for valuable input. YDNWR provided essential logistical support. We thank S. Hermens of Hermens Helicopters and H. Twitchell of YDNWR for piloting survey replicates and providing constructive feedback and insights. D.E. Andersen, D.R. Diefenbach, D.H. Johnson,

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

and L. Neel provided useful reviews of draft manuscripts. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Although PFS and BJM are employees of the U.S. Fish and Wildlife Service, the findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Service.

## LITERATURE CITED

ANDERSEN, D.E. 2007. Survey techniques. Pages 89–100 *in* D. Bird and K. Bildstein [EDS.], Raptor research and management techniques. Hancock House Publishers, Blaine, WA U.S.A.

ANTHONY, R.G., M.G. GARRETT, AND B.B. ISSASC. 1999. Double-survey estimates of Bald Eagle populations in Oregon. *Journal of Wildlife Management* 63:794–802.

BOOMS, T.L., T.J. CADE, AND N.J. CLUM. 2008. Gyrfalcon (*Falco rusticolus*). *In* A. Poole [ED.], The birds of North America online. Cornell Lab of Ornithology, Ithaca, NY U.S.A., http://bna.birds.cornell.edu/bna/species/114 (last accessed 1 February 2009).

BOWMAN, T.D. AND P.F. SCHEMPF. 1999. Detection of Bald Eagles during aerial surveys in Prince William Sound, Alaska. *Journal of Raptor Research* 33:299–304.

BUCKLAND, S.T. 2006. Point transect surveys for songbirds: robust methodologies. *Auk* 123:345–357.

BURNHAM, K.P. 1981. Summarizing remarks: environmental influences. *Studies in Avian Biology* 6:324–325.

——— AND D.R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer Science, New York, NY.

CONWAY, C.J., V. GARCIA, M.D. SMITH, AND K. HUGHES. 2008. Factors affecting detection of Burrowing Owl nests during standardized surveys. *Journal of Wildlife Management* 72:688–696.

DIEFENBACH, D.R., D.W. BRAUNING, AND J.A. MATTICE. 2003. Variability in grassland bird counts related to observer differences and species detection rates. *Auk* 120:1168–1170.

EBERHARDT, L.L., R.A. GARROTT, AND B.L. BECKER. 1999. Using trend indices for endangered species. *Marine Mammal Science* 15:766–785.

GEISSLER, P.H. AND M.R. FULLER. 1986. Estimation of the proportion of an area occupied by an animal species. Pages 533–538 *in* 1986 Proceedings of the section on survey research methods of the American Statistical Association. American Statistical Association, Washington, DC U.S.A.

GOOD, R.E., R.M. NIELSON, H. SAWYER, AND L.L. MCDONALD 2007. A population estimate for Golden Eagles in the western United States. *Journal of Wildlife Management* 71:395–402.

GRIER, J.W., J.M. GERRARD, G.D. HAMILTON, AND P.A. GRAY. 1981. Aerial-visibility bias and survey techniques for nesting Bald Eagles in northwestern Ontario. *Journal of Wildlife Management* 45:8392.

HAINES, D.E. AND K.H. POLLOCK. 1998. Estimating the number of active and successful Bald Eagle nests: an application of the dual frame method. *Environmental and Ecological Statistics* 5:245–256.

HENNEMAN, C., M.A. MCLEOD, AND D.E. ANDERSEN. 2007. Red-shouldered Hawk occupancy surveys in central Minnesota, USA. *Journal of Wildlife Management* 71: 526–533.

HENNY, C.J., M.A. BYRD, J.A. JACOBS, P.D. MCLAIN, M.R. TODD, AND B.F. HALLA. 1977. Mid-Atlantic coast Osprey population: present numbers, productivity, pollutant contamination, and status. *Journal of Wildlife Management* 41:254–265.

HINES, J.E. 2006. Presence 2.0: software to estimate patch occupancy and related parameters. USGS-Patuxent Wildlife Research Center, Laurel, MD U.S.A., http://www.mbr-pwrc.usgs.gov/software/presence/html (last accessed 1 Sept. 2008).

IVERSON, G.C. AND M.R. FULLER. 1991. Area-occupied survey technique for nesting woodland raptors. Pages 118–124 *in* B.G. Pendleton [ED.], Proceedings of the Midwest Raptor Management Symposium and Workshop. Scientific and Technical Series No. 15. National Wildlife Federation, Washington, DC U.S.A.

JOHNSON, D.H. 2008. In defense of indices: the case of bird surveys. *Journal of Wildlife Management* 72:857–868.

LINK, W.A. AND J.R. SAUER. 1998. Estimating population change from count data: application to the North American breeding bird survey. *Ecological Applications* 8:258–268.

MACKENZIE, D.L., J.D. NICHOLS, J.E. HINES, M.G. KNUTZEN, AND A.B. FRANKLIN. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84:2200–2207.

———, ———, G.B. LACHMAN, S. DROEGE, J.A. ROYLE, AND C.A. LANGTIMM. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248–2255.

———, ———, J.A. ROYLE, K.H. POLLOCK, L.L. BAILEY, AND J.E. HINES. 2006. Occupancy estimation and modeling. Academic Press, New York, NY.

MARTIN, J., C.L. MCINTYRE, J.E. HINES, J.D. NICHOLS, J.A. SCHMUTZ, AND M.C. MACCLUSKIE 2009. Dynamic multistate site occupancy models to evaluate hypotheses relevant to conservation of Golden Eagles in Denali National Park, Alaska. *Biological Conservation* 142:2726–2731.

MCDONALD, L.L. 2004. Sampling rare populations. Pages 11–42 *in* W.L. Thompson [ED.], Sampling rare or elusive species. Island Press, Washington, DC U.S.A.

MILLAR, J., S. AUDET, G. BEATTY, A. MUELLER, C. MARTINO, A. BEGAZO, C. KOPPIE, D. MULHERN, P. SCHEMPF, AND M. KLEE. 2007. Draft post-delisting monitoring plan for the Bald Eagle. U.S. Fish and Wildlife Service.

NEWTON, I. 1979. Population ecology of raptors. T. and A.D. Poyser, Berkhamsted, U.K.

NICHOLS, J.D., J.E. HINES, J.R. SAUER, F.W. FALLON, J.E. FALLON, AND P.J. HEGLUND. 2000. A double-observer approach for estimating detection probability and abundance from point counts. *Auk* 117:393–408.

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

OLSON, G.S., R.G. ANTHONY, E.D. FORSMAN, S.H. ACKERS, P.J. LOSCHL, J.A. REID, K.M. DUGGER, E.M. GLENN, AND W.J. RIPPLE. 2005. Modeling of site occupancy dynamics for Northern Spotted Owls, with emphasis on the effects of Barred Owls. *Journal of Wildlife Management* 69:918–932.

POLLOCK, K.H., J.D. NICHOLS, T.R. SIMONS, G.L. FARNSWORTH, L.L. BAILEY, AND J.R. SAUER. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. *Environmetrics* 13:105–119.

RITCHIE, R.J., A.M. WILDMAN, AND D.A. YOKEL. 2003. Aerial surveys of cliff-nesting raptors in the National Petroleum Reserve, Alaska, 1999, with comparisons to 1977. Technical note 413. U.S. Bureau of Land Management, Denver, CO U.S.A.

ROSENSTOCK, S.S., D.R. ANDERSON, K.M. GIESEN, T. LEUKERING, AND M.F. CARTER. 2002. Landbird counting techniques: current practices and an alternative. *Auk* 119:46–53.

THOMPSON, W.L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. *Auk* 119:18–25.

WINTLE, B.A., R.P. KAVANAGH, M.A. MCCARTHY, AND M.A. BURGMAN. 2005. Estimating and dealing with detectability in occupancy surveys for forest owls and arboreal marsupials. *Journal of Wildlife Management* 69:905–917.

YOCCOZ, N.G., J.D. NICHOLS, AND T. BOULINIER. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution* 16:446–453.

Received 18 October 2009; accepted 14 April 2010
Associate Editor: Ian G. Warkentin

Downloaded From: https://bioone.org/journals/Journal-of-Raptor-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use