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EFFECTIVENESS OF CALL-BROADCAST SURVEYS TO DETECT TERRITORIAL PEREGRINE FALCONS

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Abstract.—We developed and tested a 10-min call-broadcast survey protocol using conspecific vocalizations to assess Peregrine Falcon (*Falco peregrinus*) territory occupancy in the Mojave Desert of southern Nevada and northwestern Arizona from 2008–10. Response rate of peregrines, when adults were confirmed present immediately prior to broadcasting, averaged 83% during the breeding season and peaked at 100% during the courtship stage. Detection trials conducted at known occupied territories, when peregrine locations were unknown at the time of the broadcast, resulted in an average 78% detection rate across the breeding season, as compared to a 79% detection rate using the 4-hr default passive survey protocol from 2006–09. We detected peregrines in 42% of broadcast trials during the post-breeding period (September–October) in 2009. We did not observe differences in response rates related to time of day or distance from the broadcast point to the eyrie (85–1600 m). All peregrine responses during detection trials occurred within 300 sec after beginning the call-broadcast, and the mean duration of response by breeding stage diminished as the breeding season progressed. Response rates were similar by sex (male = 60%, female = 66%), but males were more likely to respond with females than alone. Peregrines often responded in the vicinity of eyries (72% of responses), a behavior we found useful for identifying eyrie ledges early in the breeding season. We found that conducting 10-min call-broadcast trials early in the peregrine breeding season at distances ≤700 m from the eyrie provided an effective means to assess occupancy.

Key Words: *Peregrine Falcon*; Falco peregrinus; *breeding*; *detection rate*; *nesting*; *Nevada*; *raptor*; *survey methods.*

EFECTIVIDAD DE MUESTREOS CON EMISIÓN DE LLAMADAS PARA DETECTAR INDIVIDUOS TERRITORIALES DE *FALCO PEREGRINUS*

Resumen.—Desarrollamos y probamos un protocolo de muestreo con emisión de llamadas de 10 minutos usando vocalizaciones de congéneres para determinar la ocupación de territorio de *Falco peregrinus* en el desierto de Mojave en el sur de Nevada y noroeste de Arizona del 2008 al 2010. La tasa de respuesta de los halcones, con presencia confirmada de adultos inmediatamente antes de la emisión, promedió 83% durante la época reproductiva y tuvo su pico de 100% durante la etapa de cortejo. Los intentos de detección realizados en territorios ocupados conocidos, cuando no se conocía la ubicación de las aves al momento de la emisión, resultó en una tasa de detección que promedió 78% a lo largo de la época reproductiva, comparada con una tasa de detección de 79% usando un protocolo por defecto de censo pasivo de 4 horas entre los años 2006 al 2009. Detectamos individuos de *F. peregrinus* en un 42% de los intentos de emisión durante el período post-reproductivo (septiembre-octubre) en 2009. No observamos diferencias en las tasas de respuesta relacionadas con la hora del día o la distancia desde el punto de emisión hasta el nido de las rapaces (85–1600 m). Todas las respuesta de los individuos de *F. peregrinus* durante los intentos de detección ocurrieron dentro de los 300 segundos después de comenzada la emisión de llamadas y la duración media de la respuesta por etapa reproductiva disminuyó a medida que la época reproductiva avanzó. Las tasas de respuesta fueron similares entre los sexos (machos = 60%, hembras = 66%), pero los machos tuvieron una mayor tendencia a responder estando con hembras que estando solos. Las rapaces a menudo respondieron en la vecindad de los nidos (72% de las respuestas), un comportamiento que encontramos útil para la identificación temprana de barrancas de nidos en la época

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reproductiva. Encontramos que realizar intentos de emisión de llamadas de 10 minutos a principios de la estación reproductiva de *F. peregrinus* a distancias ≤700 m de los nidos, resultó ser un medio efectivo para determinar la ocupación.

[Traducción del equipo editorial]

The use of call-broadcast methodology increases the likelihood of detection and decreases the amount of time required to detect many bird species (Johnson et al. 1981, Andersen 2007). Specifically, broadcasting a conspecific or interspecific call may enhance detectability of the target species by triggering a vocal or behavioral response associated with territory advertisement or defense. Enhanced detectability is especially helpful when surveying low-density populations, and birds that are otherwise secretive or difficult to detect (Johnson et al. 1981, Conway and Gibbs 2005). Call-broadcast has been useful as a survey tool for both diurnal (Kimmel and Yahner 1990, Mosher et al. 1990, McLeod and Andersen 1998) and nocturnal (Haug and Didiuk 1993, Flesch and Steidl 2006, Crowe and Longshore 2010) raptors, but has little documented use with diurnal raptors that occupy non-forested habitats (but see Salvati et al. 2000).

Despite the usefulness of call-broadcast surveys, it is important to account for imperfect detection of the target species or risk underestimating site occupancy (Rosenstock et al. 2002, Johnson 2008). As such, a survey and monitoring program will benefit from a standardized sampling protocol with high detection probability, low detection variation, and low observer variability, or which accounts for these sources of variability (Conway and Simon 2003, MacKenzie et al. 2003). There are several factors that can affect the probability of detection, including (1) the response rate, type, intensity, and duration; (2) the observer's ability to detect a response; (3) weather conditions; (4) surrounding vegetation and topography; and (5) the potential of the birds to habituate to the call-broadcast over time (Rosenstock et al. 2002, Conway and Gibbs 2005, Barnes and Belthoff 2008). In addition, the responsiveness of birds to call-broadcast can vary with the stage of the breeding season (Kennedy and Stahlecker 1993, Conway et al. 2004, Rehm and Baldassarre 2007), and time of day (McLeod and Andersen 1998, Rehm and Baldassarre 2007; but see Kimmel and Yahner 1990, DesRochers et al. 2008). Call-broadcast may also complicate discovery of territories or nests by drawing birds toward the surveyor and away from the breeding area (Conway and Gibbs 2005).

Efforts to monitor breeding populations of Peregrine Falcons (*Falco peregrinus*) to assess population recovery and range expansion, or use these top predators as bio-indicators of ecosystem health, can be constrained by the time required to verify occupancy of territories using existing survey methods. We report herein on the efficacy of using call-broadcast to facilitate rapid assessment of breeding peregrines at Lake Mead National Recreation Area (LMNRA). Prior to developing a call-broadcast approach, we used the standard post-delisting protocol for monitoring peregrines to determine occupancy and document reproductive success (USFWS 2003); however, we were limited by the time required to verify territory occupancy using this method.

Our objective was to develop and test a rapid call-broadcast survey protocol to monitor occupancy of the increasing number of peregrine territories within the LMNRA. We conducted trials to determine whether peregrines responded to conspecific call-broadcast and calculated response rates by breeding stage (i.e., courtship, incubation, nestling, and fledgling) for peregrines observed near the eyrie at the time of the broadcast. We then assessed detection rates by conducting call-broadcast trials at territories we knew were occupied, but when the surveyor was unaware if the resident birds were present at the beginning of each trial. Additionally, we evaluated the usefulness of call-broadcasting for identifying eyrie locations, and monitored response behaviors by adults.

METHODS

Study Area. We studied Peregrine Falcons in LMNRA (36°0.6′N, 114°47.8′W) within the eastern Mojave Desert. The recreation area consists of approximately 4025 km^2 of desert lands surrounding Lakes Mead and Mohave, two large reservoirs along the Colorado River. The landscape consists of open basins and sloping bajadas punctuated by numerous mountains with discontinuous cliffs and canyons. Elevations range from 192 to 1719 m asl. The area receives an average of <14 cm/yr of precipitation (Hereford et al. 2004), with vegetation primarily consisting of Mojave Desert scrub dominated by creosote bush (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*), and brittlebush (*Encelia farinosa*) along slopes and canyons. Narrow, intermittent strips of riparian vegetation line the shores of both lakes, consisting typically of salt cedar (*Tamarix* spp.), coyote willow (*Salix exigua*), and arrowweed (*Pluchea sericea*).

Passive Survey Protocol. Throughout the 2006–09 breeding seasons, we implemented a ''passive'' survey method at known peregrine territories as presented in the USFWS (2003) post-delisting monitoring plan. We defined a territory as an area containing ≥1 eyrie over time, in which only a single pair of peregrines has been known to breed each year (Steenhof and Newton 2007). We conducted a minimum of three passive surveys at territories during the breeding season: during courtship to determine occupancy; during incubation to confirm breeding attempts; and during the late nestling stage to assess productivity. Passive surveys consisted of one 4-hr monitoring session at each selected territory during peak activity periods (4 hr after sunrise and 4 hr prior to sunset), using binoculars and a spotting scope. However, we adjusted survey length as needed, extending duration to collect additional data or reducing time after attaining desired information. We conducted these surveys far enough from adults or eyries to avoid eliciting territorial behavior from attendant individuals (distance from eyrie = 127–1700 m).

Call-broadcast Protocol. We initially planned call-broadcast trials for early morning and late afternoon, in correspondence with the timing of the standard monitoring protocol (USFWS 2003). Our initial results, however, demonstrated that peregrines readily responded throughout the day, so we conducted trials throughout daylight hours when temperatures were <35°C. Our call-broadcast protocol consisted of a 10-min survey, which was divided into an initial 3-min passive observation period, followed by a 30-sec broadcast period, a 1-min observation period, a second 30-sec broadcast period, and finishing with 5 min of observation. We used recorded vocalizations from a commercially available source (Stokes field guide to bird songs: western region; Time Warner Trade Publishing, New York, New York, U.S.A.) converted to mp3 format and played on a digital game caller (FoxPro XR6; FoxPro Inc., Lewiston, Pennsylvania, U.S.A.). The conspecific calls consisted of a 5-sec ''cack'' alarm call recorded from a peregrine of the tundrius subspecies (*F. p. tundrius*) in Northwest Territories, Canada, followed by 10 sec of the ''eechup'' call from a captive adult female peregrine of the anatum subspecies (*F. p. anatum*) in Utah (White et al. 2002). Although not specified by the publisher, we believe the ''cack'' vocalization to be from a female as indicated by its relatively low frequency. During each broadcast period, we repeated the 15-sec broadcast cycle described above one time for 30 sec of continuous calling, while rotating the game caller 360°. We broadcasted at a volume of 84–90 dB, as measured 1 m from the caller by a sound-level meter set on slow response and C-weighting (Fuller and Mosher 1987). We did not conduct trials during precipitation or when sustained wind speeds were ≥16 km/hr. To minimize disturbance to breeding peregrines, we ceased broadcasting immediately after detecting a response from a peregrine.

To test the effectiveness of our protocol, we conducted call-broadcast trials at known occupied territories, where we previously observed territorial defense, paired adults, or other reproductive activity (Steenhof and Newton 2007). During the courtship stage, we based broadcast points on eyrie locations from the previous year, whereas broadcast points during later stages were based on the current year's eyrie. Given constraints imposed by the rugged nature of the terrain surrounding eyries, as well as limitations we faced detecting audible and visual cues of peregrines, we attempted to conduct trials within a range of 200–700 m from eyries, or eyrie cliffs when actual eyrie ledges were unknown. We documented peregrine eyries on cliffs averaging 100 m in height (range = 12–270 m). When we did not know eyrie locations, we placed call-broadcast points near the area considered most likely to contain an eyrie and measured distance to eyries after we discovered them. We measured all distances using a laser range finder with an accuracy of ±0.3 m (TruPulse 200 B, Laser Technology Inc., Centennial, Colorado, U.S.A.).

We defined a peregrine response to be a vocalization or flight initiated after we began broadcasting through the remainder of the call-broadcast trial (Balding and Dibble 1984, McLeod and Andersen 1998). Because we could not always be certain that a detected action was related to the call-broadcast, we noted any evidence that would lead us to believe the action was related to some other cue (e.g., an adult delivering prey to the eyrie during the trial period) and did not count the action as a response. We recorded each type of response (i.e., flight, vocal, flight and vocal) and documented the sex and age class (i.e., nestling, fledgling, subadult, adult) of each peregrine involved. We recorded latency of response in seconds, defined as the time between the start of broadcasting to the moment we first detected a response. We measured the duration of response in minutes, considering a response to have ended when the responding peregrines remained silent or inactive for ≥2 min.

To assess whether call-broadcasts reduced the time required to find eyries, we assigned each response to focal areas, which we defined as the area from which a response took place or to where the peregrine flew during the response. We categorized peregrine responses as occurring: (1) toward the call-broadcast point (i.e., flying toward the vicinity of the broadcast point); (2) within the vicinity of the eyrie (e.g., departing from and returning to the eyrie, vocalizing while perched on the eyrie ledge, or concentrating the display within 30 m of the eyrie); or (3) toward or from some other area. To evaluate whether call-broadcasts may negatively affect breeding success, we monitored the reaction of incubating or brooding adults, recorded the duration of any resulting time away from the eyrie (monitoring beyond the 10-min trial period when necessary), and watched for evidence of disturbance to eggs or young (e.g., dislodging by adults as they left the eyrie).

Timing of Trials. We conducted call-broadcast trials during the breeding season from 18 February to 24 June in 2008, from 25 February to 29 July in 2009, and during the fledgling stage in 2010 from 30 June to 2 July. By breeding stage, we conducted trials during the courtship (mid-February through March), incubation (April to mid-May), nestling (May to mid-June), and fledgling (June and July) stages. We also conducted trials in 2009 during a post-breeding period from 23 September through 22 October. We added territories to our study as we discovered previously unknown territories and ceased testing at others after we confirmed breeding failure. Inclement weather sometimes limited our ability to conduct call-broadcast trials at territories during each breeding stage.

Monitoring within LMNRA from 2006–10 indicated on average the earliest females began laying eggs on 13 March, and each year an average of 42 d separated the date that the first pair laid eggs from the date for the last pair (Barnes 2011). We determined the breeding stage during each trial by observing behavioral cues (e.g., aerial courtship displays, incubating posture, feeding young), or assigned breeding stage to earlier trials by back-dating after estimating the age of young. We viewed nestlings using binoculars and a spotting scope, and estimated age based on a photographic aging guide (Cade et al. 1996). We then used published lengths of breeding stages (i.e., incubation = 31 d, nestling = 42 d; Cade et al. 1996) to estimate incubation and hatch dates. Our trials during the fledgling stage occurred while young were in the vicinity of the eyrie and were dependent on adults for food (trials averaged 14.6 d after estimated fledging date).

Response Trials. To estimate the likelihood of response and document the types of responses of peregrines to call-broadcasts, we conducted response trials at territories after first confirming, through passive monitoring, the presence of ≥1 adult, subadult, or fledgling in the vicinity of the eyrie immediately prior to broadcasting. For response trials, we modified our 10-min call-broadcast survey protocol by extending the length of the first passive observation period as needed to detect an attending peregrine (longest duration was 300 min). We conducted response trials in 2008 during courtship, incubation, nestling, and fledgling stages. We conducted only a limited number of response trials during the fledgling stage ($n = 5$) because surveys later in the breeding season are of limited value when establishing territory occupancy or estimating reproductive success (Mayfield 1961, Steenhoff and Kochert 1982).

Detection Trials. To estimate the likelihood of detecting peregrines at territories using our 10-min call-broadcast protocol, we conducted detection trials when the presence of peregrines at the eyrie cliff was not known to the observer at the time of the trial. We conducted detection trials during each of the breeding season stages in 2009, followed by a post-breeding period in September and October, and additional trials during the fledgling stage in 2010. We repeated detection trials at many territories within breeding stages to assess whether detection rates changed over time.

Statistical Analyses. *Response rates.* We calculated peregrine response rates as the number of times ≥1 peregrine responded per number of response trials conducted within each breeding stage. Our small sample sizes per breeding stage were insufficient to support a generalized linear model (GLM) approach. Instead, from 1000 bootstrap replicates we estimated 95% confidence intervals based on quantiles for each year, and year-stage combination (Efron and Tibshirani 1998). We conducted this analysis using R 2.8.1 (R Development Core Team 2008).

Detection rates. We calculated detection rates as the number of times we detected $\geq$1 peregrine per number of detection trials conducted within each stage. We compared these rates between breeding stages for the first trial at each territory per breeding stage using a GLM with binomial error (Sokal and Rohlf 1995). The model included a random territory effect to account for repeated measurements at territories throughout the breeding season and to avoid pseudoreplication. We conducted Tukey post hoc tests to assess significance ($\alpha = 0.05$), and we report the least squares means of detection rates during each breeding stage. We fit all GLMs using SAS 9.1 (SAS Institute 2002–08).

We used a Fisher's exact test to assess whether detection rates were different with repeated visits at territories within breeding stages using three categories: no response in either visit, response in at least one visit, or response in both visits. We combined data from the 2009 and 2010 fledgling stages to increase sample size and because there was no overlap in territories between the two data sets. We conducted all Fisher's exact tests using R. We also tested for an effect of number of days after previous visit (within and between stages) using logistic regression in SAS with detection as the dependent variable, the number of days after the previous visit as the independent variable, and a random territory effect. Both of these analyses were limited to those territories that had visits repeated within a breeding stage.

Latency and duration of response. We analyzed latency (time to response) and duration of response during the first visit per stage of detection trials with linear models, with breeding stage as the only fixed effect, and a random repeated measures effect by territory to avoid pseudoreplication. We modeled latency as a Poisson variable, whereas a $\log_{10}$ transformation of duration of response was approximately normal and homoscedastic. We performed Tukey post hoc tests to assess significance of stage effects when main effects were significant ($\alpha = 0.05$). To further characterize latency, we conducted a survival analysis and used one minus the product-moment survival to estimate the proportion of birds responding to a broadcast as a function of time (SAS proc Lifetest).

Other response variables. We analyzed the data from first visits of territories within a breeding stage during detection trials to assess effects on detection rates by time of day and distance between the broadcast and the eyrie. For the courtship stage, we considered the number of days before laying at the time of each trial to model whether there was a change in detection rate as females approached clutch initiation. Because the data were unbalanced within territory (not all breeding stages were represented at each territory) and sample sizes were not large within stages, we conducted separate logistic regression analyses (with random territory effects) for effects of time of day, distance from eyrie, and days before laying on detection rates. We looked for differences in the type of response (i.e., flight, vocal, or both) by breeding stage using a chi-square contingency test in R.

To determine how sex and stage affected the likelihood of peregrine response, we fit a GLM with binomial error and main effects of sex and stage. This model was restricted to cases in which we confirmed the presence of peregrines by sex at the time of broadcast. To assess whether peregrines responded to call-broadcast independently by sex across breeding stages, we fit a GLM with binomial error containing main effects of male (response or no response), female (response or no response), and stage, along with two-way interactions. We interpreted significant results using Fisher's exact tests and values expected if males and females behaved independent of one another.

RESULTS

We conducted 269 passive surveys using the recommended USFWS (2003) protocol at 35 peregrine territories throughout the 2006–09 breeding seasons. Pooling data across breeding stage and year, passive surveys averaged 130.8 min/survey (range = 7–359 min; Table 1) and we detected adult peregrines during 79% of surveys. We did not detect adult peregrines during 56 passive surveys (21%), and these surveys averaged 140.9 min (SD = 76.4) in length.

We conducted 217 call-broadcast trials at peregrine territories while testing our method from 2008–10. Of these, we performed 49 as response trials when we confirmed the presence of peregrines prior to conducting trials at 23 territories during the 2008 breeding season (courtship–fledgling). The average amount of time we spent passively observing at territories during response trials prior to initiating call-broadcasts was 71.1 min (SD = 72.5 min, range = 1–300 min, $n = 49$). We conducted all subsequent trials as detection trials without knowledge of whether peregrines were present in the vicinity of the eyrie cliff. In 2009, we conducted

Table 1. Detection rates (the ratio of the number of surveys with detections to the total number of surveys) and mean duration of passive surveys for Peregrine Falcons within Lake Mead National Recreation Area, Nevada and Arizona, 2006–09. Duration of each survey varied due to the time required to gather occupancy and reproductive data per breeding stage. At times, surveys were shortened due to inclement weather or lack of daylight and were extended when conditions allowed. Surveys in which we confirmed breeding failure are listed as ''Failed,'' whereas surveys in which we could not determine breeding stage are listed as ''Unknown.''

SURVEY CATEGORY	*n*	MEAN TIME/ SURVEY (min)	SD (min)	RANGE (min)	DETECTION RATE
Courtship	82	131.1	81.2	9–299	0.805
Incubation	35	131.3	70.9	10–290	0.914
Nestling	62	101.3	70.1	7–300	0.919
Fledgling	28	108.5	70.1	25–268	0.821
Failed	18	163.3	64.0	50–260	0.444
Unknown	44	172.7	77.9	57–359	0.614
Total	269	130.8	78.8	7–359	0.792

131 detection trials at 29 territories throughout the breeding season; 54 of these trials were repeat visits conducted at territories within breeding stages. Additionally, we conducted detection trials at 24 territories (one visit per territory) during a post-breeding period in 2009 (September–October), and conducted 13 trials at 8 territories during the fledgling stage in 2010.

Response and Detection. Pooling across stages of the 2008 breeding season, peregrines responded to call-broadcast during 83% of response trials (n = 49) when we had confirmed presence prior to conducting trials. Response rates declined from 100% during the courtship stage to 73–80% later in the breeding season (Fig. 1). Response rates were not significantly different among breeding stages based on overlapping bootstrapped confidence intervals.

During detection trials, when the observer did not know if peregrines were present at the time of the trial, we detected peregrines during 78% of all first visit trials pooled across the 2009 breeding season (n = 77). Detection rates were 79% during courtship, peaked during incubation (90%), and then dropped during the later stages of the breeding season (Fig. 2). Results from the GLM indicated detection rates were not significantly different among stages of the breeding season, but were significantly lower during the post-breeding period (42%) than all breeding stages except the fledgling stage ($F_{5,73} = 3.13$, $P = 0.013$; Fig. 2). For territories

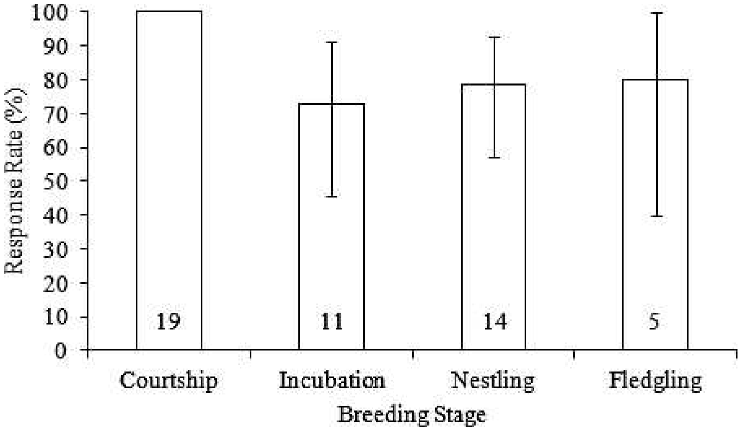

Figure 1. Response rates of resident Peregrine Falcons during call-broadcast response trials in Lake Mead National Recreation Area, Nevada and Arizona, during the 2008 breeding season. Bars include bootstrapped 95% confidence intervals. Numbers at the base of each bar indicate sample size.

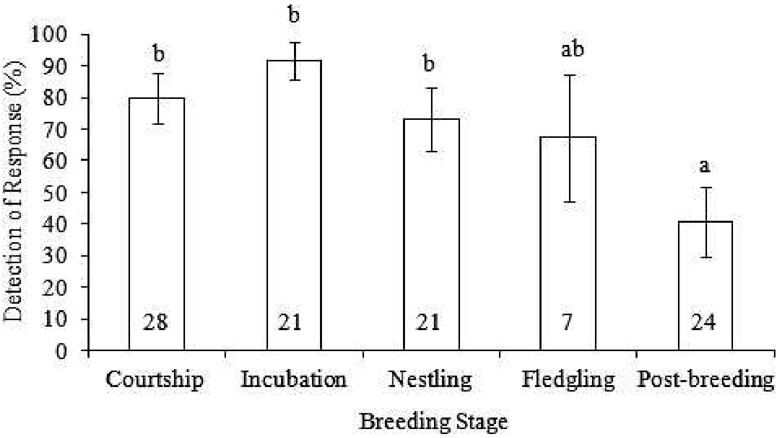

Figure 2. Detection rates of Peregrine Falcons during call-broadcast detection trials in Lake Mead National Recreation Area, Nevada and Arizona, during the 2009 breeding season and a post-breeding period (September–October). Results presented are the back-transformed least squares means ± SE for the first trial at each territory by breeding stage. Letters above each bar indicate means that are significantly different from means of stages with other letters (Tukey test, $P < 0.05$), and numbers at the base of each bar indicate sample size.

in which we conducted at least one detection trial in both the courtship and incubation stages ($n = 20$), we confirmed occupancy at all territories (i.e., we detected peregrines at each territory during either courtship or incubation) and detected peregrines in 32 of 40 trials in the two stages combined. During the courtship stage, the number of days before laying (trials conducted from 6–56 d before laying) was not related to detection rate ($F_{1,52} = 0.18$; $P = 0.675$).

During passive observation periods prior to broadcasting (response and detection trials), we did not document peregrines reacting to our presence vocally or with aerial displays. We initially detected peregrines within the 3-min passive observation period prior to broadcasting during 32% of all detection trials. Peregrines responded to the broadcast during 80% of these detection trials after we initially detected peregrines prior to broadcasting.

When we repeated detection trials within breeding stages ($n = 59$), we obtained lower detection rates during second visits (56%) than during first visits (75%) pooled across stages (Table 2). We detected a significant negative relationship overall (within and among stages) between the number of days after the previous visit and detection rate ($F_{1,53} = 6.60$; $P = 0.013$); however, within each breeding stage and pooled across stages there was no relationship between detection rate and the number of days since the previous visit ($F_{1,34} = 0.54$; $P = 0.468$).

Table 2. Detection rates (the ratio of the number of trials with detections to the total number of trials) of Peregrine Falcons during call-broadcast detection trials in Lake Mead National Recreation Area, Nevada and Arizona. Detection rates are presented for the first and second visits per breeding stage, for detection during any single visit, and detections during both visits. The number of observations (n) represents the number of territories with repeat trials within each breeding stage. The fledgling stage includes trials conducted in 2009 and 2010, whereas trials during all other stages occurred in 2009.

Breeding Stage	n	Mean Days Between Visits	Detection Rates		Detected in One Visit	Detected in Both Visits
			1st Visit	2nd Visit		
Courtship	20	6.8	0.80	0.65	0.85	0.60
Incubation	15	5.5	0.87	0.60	0.93	0.53
Nestling	18	12.4	0.72	0.50	0.78	0.44
Fledgling	6	3.2	0.33	0.50	0.67	0.17

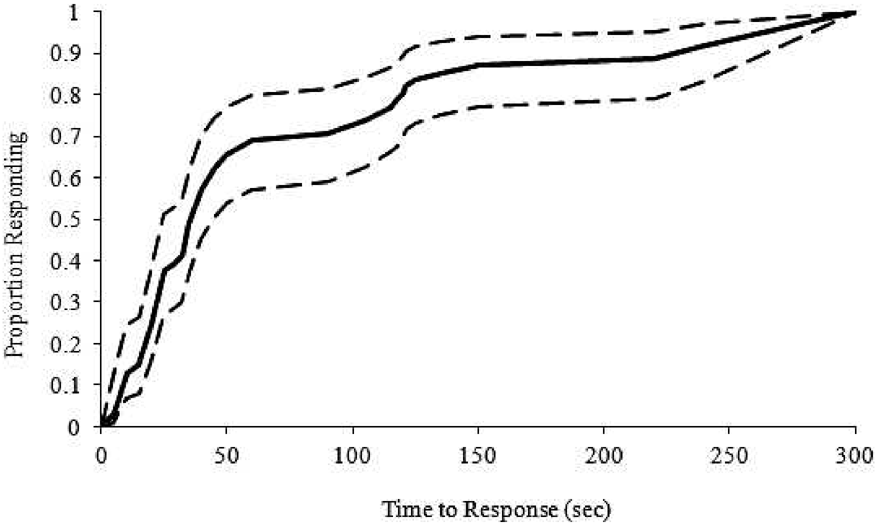

Figure 3. Observed distribution of the cumulative proportion of Peregrine Falcons responding as a function of time to response to call-broadcasts within Lake Mead National Recreation Area, Nevada and Arizona. Results are pooled across breeding stage during the detection trials in 2009 and include trials during the 2010 fledgling stage. The area between dashed lines represents a 95% confidence envelope based on pointwise confidence intervals of the survival function.

Within the same breeding stage and pooled across stages, the mean number of days between visits was 7.8 d (Table 2).

Time of Day and Distance from Eyrie. The overall mean distance of our call-broadcast trial locations to eyries was 382 m (range = 85–1600 m), and the average distance of the first responding peregrine to the broadcast point was 351 m (range = 70–1100 m). Whereas we conducted most trials within 700 m of the eyrie (95% of trials), the maximum distance of broadcast point to an eyrie in which we detected a response was approximately 1600 m; this occurred during the courtship stage before we determined that year's eyrie location. During the breeding season, we conducted trials from 0526–1948 H, PST. Morning trials (sunrise to 1000 H) accounted for 61% of all trials, whereas we conducted 30% of all trials in midday (1001–1500 H), and 10% in the evening (1501 H to sunset). Detection of peregrines was not significantly related to time of day ($F_{1,77}$ = 0.03; P = 0.863) or distance between the broadcast point and the eyrie ($F_{1,77}$ = 0.67; P = 0.417).

Latency and Duration of Response. Latency did not vary by breeding stage ($F_{5,27}$ = 2.05, P = 0.103). During detection trials, we noted 89% of responses within 180 sec following the start of broadcasting, and 100% of responses within 300 sec (Fig. 3). By stage, mean time to response (±SE) increased from 65 ± 16 sec (n = 21) in courtship to a maximum of 146 ± 36 sec (n = 9) during the nestling stage. We observed a change in duration of response across stages ($F_{5,27}$ = 4.2, P = 0.006), with responses during the fledgling stage being shorter than those in all other stages except nestling (Fig. 4). In general, response durations became shorter with each successive breeding stage, before lengthening in the post-breeding period. We recorded an overall mean duration of response throughout all response and detection trials of about 3.5 min (n = 133, range = 0.08–19 min).

Response Type. The type of response did not differ significantly among breeding stages (χ^2_8 = 7.51, P = 0.482, n = 127) during response and detection trials. However, during the breeding season, responses involving both flight and vocal elements were the most common, composing 63% of all responses during courtship and declining to 42% by the fledgling stage. Responses in which peregrines took flight but remained silent accounted for 23% of responses in courtship, 14% during incubation, and 33% in the fledgling stage. Responses in which peregrines vocalized but did not take flight made up only 13% of responses in courtship, 29% of responses during the nestling stage, and 25% after young fledged.

Response by Sex. Pooled across year and breeding stage, adult males were involved in fewer responses (45%) than adult females (69%; Table 3),

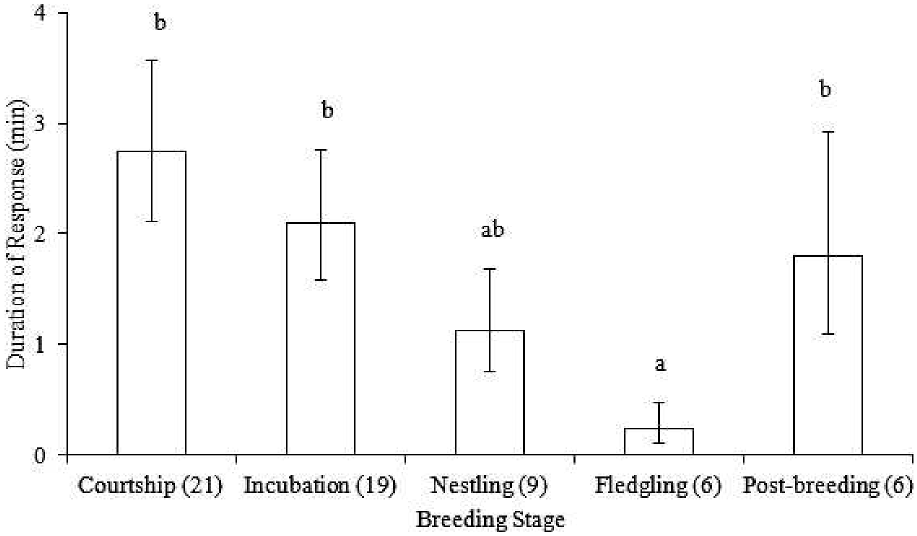

Figure 4. Duration of all Peregrine Falcon responses in Lake Mead National Recreation Area, Nevada and Arizona, during detection trials throughout the 2009 breeding season and post-breeding period (September–October), and the fledgling stage (2009 and 2010 fledgling stages pooled). The back-transformed least squares means ± SE are presented for the first visit at territories per breeding stage. Letters above each bar indicate means that are significantly different from means of stages with other letters (Tukey test, $P < 0.05$). Numbers in parentheses after each stage name indicate sample size.

but this difference was not statistically significant ($F_{1,3} = 0.81$, $P = 0.433$). We also did not observe a significant effect of stage on male and female responses ($F_{3,3} = 5.29$, $P = 0.102$), although power to detect differences may have been hampered by small sample size in the latter stages. Males responded alone infrequently (12 of 127 total responses), but whether males responded was positively related to a female response (45 mutual responses; $F_{1,12} = 8.15$, $P = 0.015$). Pooled across year and breeding stage, sex response rates were similar, and in cases when at least one individual of each sex was confirmed present, males responded 32 (60%) of 53 times, whereas females responded in 45 (66%) of 68 response and detection trials. Response rates for both males and females showed a declining trend from the courtship to nestling stages; males from 71% to 23%, and females from 85% to 42%.

Responses and Young. We seldom observed peregrines responding in certain situations involving offspring. Adults appeared to limit responses to the broadcast during the nestling stage when provisioning young just prior to, or during, the first broadcast period ($n = 7$, with only one response). We also documented only a single response from nestlings during 53 trials during the nestling stage

Table 3. Participants in Peregrine Falcon responses by sex and age during call-broadcast (response and detection trials) in Lake Mead National Recreation Area, Nevada and Arizona, 2008–10. Responses by both breeding adults comprise a pair, whereas any responding offspring are indicated by breeding stage. The number of responses per breeding stage (n) indicates trials with peregrine responses.

		Participants				
Breeding Stage	n	Male Only	Female Only	Pair	Unknown Adult	Offspring
Courtship	52	4	16	23	9	0
Incubation	35	3	13	15	4	0
Nestling	28	2	12	6	8	1
Fledgling	12	3	2	1	2	5
Total (%)	127	12 (9.4)	43 (33.9)	45 (35.5)	23 (18.1)	6 (4.7)

and, on three occasions, nestlings that had been vocalizing became quiet immediately after we broadcast calls. During the fledgling stage, young responded during five (19%) of 26 trials; however, during two of these instances vocalizing fledglings quickly became quiet at the onset of call-broadcast. During six trials, fledglings that had been detected passively prior to broadcasting did not respond to call-broadcasts.

During the incubation and early nestling stages, we confirmed on 27 occasions (23 female, 4 male) the presence of an adult peregrine in the eyrie and in low incubating or brooding posture prior to call-broadcast. The incubating adult responded 19 times (70% response rate), and in 17 of these responses the adult ceased incubating or brooding and departed the eyrie. In two instances, neither adult returned to tend the young prior to the observer leaving the site (>15 min and 17 min), but during each of the other 15 responses an adult returned after an average of 2.1 min (range = 1–4 min). During 13 of 23 instances when we confirmed a female in the eyrie incubating or brooding young, she did not begin vocalizing until shortly after departing the eyrie and perching 20–50 m away. After vocalizing for 1–3 min, females generally became quiet 10–30 sec before returning directly to the eyrie. We found this behavior to be quite useful in confirming the location of eyrie ledges.

Response Focal Area. Peregrines focused 72% of their responses within the vicinity of the eyrie during the first three breeding stages (courtship 30 of 46; incubation 30 of 35; nestling 19 of 28). Only rarely (<4% of responses) did peregrines fly to the vicinity of the broadcast point while responding. During courtship, we detected responses during 19 of 26 trials in which the peregrines went on to use eyrie ledges that were different from those used in the previous year. Four of these responses were performed in the vicinity of the previous year's eyrie, five in the vicinity of the ledge on which the current year's eyrie was later located, and in eight responses the peregrines flew back and forth between the two eyrie locations.

DISCUSSION

Peregrine Falcons in southern Nevada and northwestern Arizona responded readily and consistently to conspecific calls broadcasted as part of a standardized call-broadcast survey. Response and detection rates were highest during courtship and incubation and remained high through the nestling stage. Whereas our efforts were focused on early stages of breeding, peregrines also responded to call-broadcasts during the fledgling and post-breeding stages, although at lower rates than during earlier breeding stages. High response and detection rates early in the breeding season were useful for assessing territory occupancy and reproductive effort, allowing us to identify breeding attempts early in the breeding season and document breeding attempts at territories that might not be occupied after early reproductive failure.

The use of call-broadcast allowed us to greatly reduce the time required to document the presence of peregrines when compared with the passive 4-hr monitoring protocol currently in use (USFWS 2003). Our 10-min call-broadcast protocol compared favorably with the passive methodology in terms of detection rates and verification of territory occupancy, particularly during the courtship and incubation stages. We recognize that the passive survey approach was designed to collect eyrie location and reproductive success data, in addition to territory occupancy, whereas our call-broadcast method was primarily intended to obtain occupancy data. Nevertheless, we found that by eliciting responses from resident peregrines, our method was useful for detecting breeding pairs, as both members of resident pairs often responded together. Importantly, resident peregrines often focused responses in the vicinity of eyries, enhancing our ability to quickly determine breeding status and identify eyrie location.

Prior to initiating our call-broadcast trials, we considered the possibility that females might be particularly sensitive to disturbance during the laying and incubation stages (Fuller and Mosher 1981, Kennedy and Stahlecker 1993, McClaren et al. 2003). Whereas incubating peregrines had a relatively high response rate (70%), in all cases when the adult responded it left the eyrie without noticeably dislodging eggs or young. Peregrines that did not detectably respond to call-broadcasts remained in incubating posture throughout the trial period. Furthermore, the short period during which eggs or young were left untended led us to conclude that peregrine breeding attempts were likely not adversely affected by call-broadcasts. Furthermore, apparent breeding success (number of successful pairs/number of breeding attempts) in 2008 and 2009 (mean = 0.691) during the bulk of our study, was similar to that observed in 2007 and 2010 (mean = 0.687; Barnes 2011).

In our study, conducting repeat detection trials within breeding stages did not significantly increase detectability. In all stages other than fledgling, we recorded a drop in detection rates during second visits, although there was no relationship between detection and the number of days between repeat visits within stages. A possible explanation is that peregrines habituate to broadcasts; however, detection rates generally increased from the second visit in the previous stage to the first visit in a subsequent stage (except between nestling and fledgling stages). This apparent paradox may be explained in that the average time between the visits within the same stage was 8 d, whereas the average time between the second visit of the previous stage and the first visit of the following stage was 32 d. Habituation effects, if present, may lessen during the longer interval between stage visits. Responsiveness of breeding peregrines to conspecific call-broadcast, however, may be affected by various factors associated with timing within the breeding season, differing parental care strategies, and variable hormone levels. As observed with detection rate, duration of response also declined as the breeding season progressed.

Detection probability is also potentially affected by the sex and age of the bird (Joy et al. 1994, Andersen 2007), with sex a particularly important factor in species such as peregrines that divide hunting and incubation tasks during the breeding season (Rosenfield et al. 1988). In our study, however, we did not detect overall statistically significant differences in the response rates of males and females, or a difference in sex-specific response across stages. Nevertheless, male peregrines were involved in fewer responses than females, and were less likely to respond when only one adult was involved. Our broadcasted call consisted of a female ''eechup'' and a ''cack'' (likely from a female) vocalization. We speculate that the sex-specific broadcasts may elicit more responses from females than from males due to the perceived threat to breeding status broadcasted female calls may present to resident females. We also noted a trend in the response rates of both sexes with the lowest response rates during the nestling stage, possibly to avoid drawing attention to their young; Roberson et al. (2005) proposed this explanation for a similar pattern observed in Northern Goshawks (*Accipter gentilis*). Our observations of peregrine young indicated they did not generally respond audibly (becoming quiet on several occasions) to our call-broadcasts, although we did not test other calls, such as begging, that may elicit more responses from young.

Based on our testing, we recommend peregrine call-broadcast surveys should consist of an initial period of passive observation, followed by at least one call-broadcast period and a final observation period to compensate for any lag time in response. It may be helpful to extend the length of the final observation period to collect reproductive success data (e.g., confirming incubation and aging nestlings). This approach would allow for the detection of peregrines that may otherwise be nonresponsive, while eliciting a response from others to increase detection. In our study, peregrines responded to broadcasts throughout the day, although it is not known whether diurnal pattern of response varies geographically. We found trials during the courtship and incubation stages were most effective for confirming territory occupancy and most useful for tracking breeding attempts based on high detection rates and response duration. For reproductive studies, repeat surveys may be most effective when replicates are conducted across the courtship and incubation stages (rather than within stages), increasing the ability to confirm breeding attempts and pinpoint eyrie locations.

We did not find detection rate to be related to distance from the eyrie, although our ability to detect differences was reduced by low sample size (only 5% of trials conducted >700 m from the eyrie). We expect that further research will find detection rate of peregrines decreases with distance from eyries, which will influence the optimal distance to eyries and spacing of broadcast points. We found broadcast points were highly effective when located ≤700 m from eyries to detect peregrine responses; however, this may vary regionally depending on environmental conditions. The effective range of our call-broadcast method may be reduced substantially due to sound attenuation in areas where dense vegetation or canopied forests surround nest sites (e.g., Marten and Marler 1977, Richards 1981). McClaren et al. (2003) speculated that lower detection rates of goshawks in dense forests, in relation to arid open forests (Kennedy and Stahlecker 1993), may be partially due to increased attenuation of sound from high tree density. Areas in which snow persists may also exhibit different distances of unattenuated sound transmission, as might coastal areas with high levels of background noise. Additionally, visual detection of flight responses will likely be hindered in forested areas compared to the generally open, arid lands within our study area.

We encourage additional testing of call-broadcast methodology with peregrines, including assessment of response to different call types. Local breeding density and the presence of a nonbreeding floater population may also influence peregrine responsiveness. Before implementing call-broadcast methodology, we advise assessing detection probability and variability at known occupied territories to assess potential local differences from the conditions we encountered.

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