J. Raptor Res. 37(3):198–208

EFFICACY OF MALE GOSHAWK FOOD-DELIVERY CALLS IN BROADCAST SURVEYS ON VANCOUVER ISLAND

ERICA L. MCCLAREN[1]
Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523 U.S.A.

PATRICIA L. KENNEDY[2]
Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523 U.S.A.

PHILLIP L. CHAPMAN
Department of Statistics, Colorado State University, Fort Collins, CO 80523 U.S.A.

ABSTRACT.—We conducted broadcast experiments at occupied Northern Goshawk (*Accipiter gentilis laingi*) nest sites on Vancouver Island, British Columbia, during the 1998 (N = 8) and 1999 (N = 11) breeding seasons to examine the potential of the untested male food-delivery call to improve detection rates. We compared the male food-delivery call to standard vocalizations used to locate Northern Goshawk nests during each breeding phase. An adult alarm and male food-delivery call were broadcast during the courtship (1999 only), nestling, and fledgling-dependency breeding phases, whereas a juvenile-begging call was broadcast only during the latter phase, when young were sufficiently developed to respond to calls. Northern Goshawks were detected at 52% (N = 88) of all broadcast trials. The male food-delivery call did not improve detection rates throughout the breeding season. Detection rates were lowest (40%) during courtship and highest (75%) during the fledgling-dependency phase. The distance we detected Northern Goshawks from nests with male food-delivery and alarm calls increased between courtship and nestling phases to the fledgling-dependency phase when the majority of detections shifted from adults to fledglings. Breeding phase did not influence the probability of detecting goshawks with male food-delivery and alarm calls. Broadcasting the juvenile-begging call within the fledgling-dependency phase increased the probability of detecting Northern Goshawks relative to the other two call types. The alarm and juvenile-begging calls remain the most effective for detecting Northern Goshawks on Vancouver Island during the nestling and fledgling-dependency periods, respectively. Dense coastal vegetation and rugged terrain may have interfered with our ability to project broadcast calls and to detect Northern Goshawks. The efficacy of broadcast surveys in Pacific Northwest forests during the nestling phase may be improved by spacing broadcast stations and transects at 200-m intervals, rather than the current standard of 300-m intervals, when detections occur close to nests. Broadcast stations and transects could be spaced 400-m apart during the fledgling-dependency phase when fledglings are detected farther from nest sites.

KEY WORDS: *Northern Goshawk;* Accipiter gentilis laingi; *alarm call; broadcast surveys; juvenile-begging call; male food-delivery call; mixed models.*

EFICACIA DE LAS VOCALIZACIONES DE ENTREGA DE ALIMENTO DEL MACHO DE AZOR SEPTENTRIONAL EN INVESTIGACIONES HECHAS EN LA ISLA DE VANCOUVER

RESUMEN.—Llevamos a cabo experimentos con la emisión de vocalizaciones en los sitios de anidación ocupados por el azor septentrional (*Accipiter gentilis laingi*) en la Isla de Vancouver, British Columbia, durante las temporadas de crianza de 1998 (N = 8) y 1999 (N = 11) con el propósito de examinar el potencial de las vocalizaciones del macho a la entrega de alimento y con el fin de mejorar las tasas de detección de las mismas. Comparamos la vocalizacion de entrega de alimento del macho para su estandarización y para localizar nidos del azor septentrional durante cada fase de cría. Una vocalizacion de alarma del adulto y otra de entrega del alimento del macho se transmitieron durante el cortejo (sólo

---

[1] Present address: Ministry of Water, Land, and Air Protection, 2080A Labieux Rd., Nanaimo, BC V9T 6J9 Canada.
[2] Corresponding author's present address: Eastern Oregon Agricultural Research Center, Union Experiment Station, P O. Box E, 372 So. 10th, Union, OR 97883 U.S.A.; e-mail address: Pat.Kennedy@orst.edu

en 1999), la anidación, y las fases de apareamiento y dependencia de volantón, mientras que una vocalización de un juvenil pidiendo alimento se transmitió sólo durante la última fase, cuando los juveniles estuvieron lo suficientemente desarrollados para responder a las vocalizaciones. Los azores septentrionales se detectaron en 52% (N = 88) de todos los ensayos de emisión. La vocalizacion de entrega del alimento del macho, no mejoró las tasas de detección a través de la temporada de cría. Las tasas de detección fueron bajas (40%) durante el cortejo y altas (75%) durante la fase de dependencia del volantón. La distancia detectada desde los nidos con las vocalizaciones de entrega de alimento y de alarma, aumentaron entre el cortejo y la fase de anidación hasta la fase de dependencia del volantón, cuando la mayoría de las detecciones cambiaron de adultos a volantones. La fase de cría no influyó en la probabilidad de discernir las llamadas de entrega de alimento y de alarma. La emisión de la vocalizacion de juveniles pidiendo alimento dentro de la fase de dependencia de volantón aumentó la probabilidad de detectar a los parientes del azor septentrional de otros dos tipos de vocalizaciones. Las vocalizaciones de alarma y las de juveniles pidiendo alimento son las más efectivas para detectar azores septentrionales en la Isla de Vancouver durante los períodos de cría y de dependencia del volantón, respectivamente. La densa vegetación costera y el terreno escabroso pudieron haber interferido en nuestra habilidad de proyectar la emisión de las vocalizaciones y para detectar los azores. La eficacia en las emisiones en los bosques del noroeste del Pacífico durante la fase de cría pueden mejorarse espaciando las estaciones de transmisión y los transectos en intervalos de 200 m, en lugar de los intervalos estándar actuales de 300 m, cuando las detecciones se dan cerca de los nidos. Las estaciones de emisión y los transectos se podrían espaciar 400 m, durante la fase de dependencia de volantón cuando estos se detectan más lejos de los sitios de anidación.

[Traducción de César Márquez]

Techniques used to sample avian populations have come under recent scrutiny (Nichols et al. 2000, Rosenstock et al. 2002, Thompson 2002). In particular, scientists are concerned with sampling methods that generate abundance estimates that assume equal (and often 100%) detection rates across all species, age groups, habitat types, and time periods (Anderson 2001). Without incorporating detection probability functions into abundance estimates to adjust for these factors, the results produced are suspect, at best. Unbiased and accurate abundance estimates for avian populations are essential to monitor changes in population abundance, elucidate avian-habitat relationships, and detect population responses to environmental change (Rosenstock et al. 2002, Thompson 2002).

Abundance estimates for songbirds derived from point-count methodology have been the target of most sampling criticism. However, abundance estimates derived from broadcast surveys (also referred to as acoustic lure, call playback, or call response surveys) may be equally problematic because they are based on similar assumptions. Broadcast surveys are used to detect several elusive bird taxa including waterbirds (Legare et al. 1999, Erwin et al. 2002), frogmouths (Smith and Jones 1997), owls (Bosakowski and Smith 1998, Reid et al. 1999, Hardy and Morrison 2000), and hawks (Mosher and Fuller 1996, Bosakowski and Smith 1998, McLeod and Andersen 1998).

Broadcast surveys of conspecific calls are the most widely used technique to detect breeding Northern Goshawks (*Accipiter gentilis*; hereafter referred to as goshawk) throughout North America (New Mexico/Arizona: Kennedy and Stahlecker 1993, Arizona: Joy et al. 1994, Washington: Watson et al. 1999, British Columbia: McClaren 2001, Minnesota: Roberson 2001). Through broadcast survey experiments at known, occupied nests in Arizona and New Mexico, Kennedy and Stahlecker (1993) demonstrated broadcast surveys were 89% effective at detecting breeding goshawks and their young throughout the breeding season. They showed the alarm call was most effective during the nestling phase and the juvenile-begging call was most effective during the fledgling-dependency phase. Using similar experimental techniques in Washington, Watson et al. (1999) elicited 56% detection rates from breeding adults and their young. This suggests the effectiveness of broadcast surveys to detect breeding goshawks varies and may be influenced by habitat type, with detection rates being lower in the dense, coastal forests of the Pacific Northwest.

Variable, and perhaps, low, goshawk detection rates from broadcast surveys limit our ability to discern population trends and the influence of forest harvesting on breeding-habitat suitability. As a result, goshawk rates of population change and habitat associations remain unclear and are controversial (Crocker-Bedford 1998, Kennedy 1998, Smallwood 1998). In an effort to increase goshawk detection rates through broadcast surveys, we provide the first rigorous test of the male goshawk food-delivery call. This vocalization has been phonetically described as *kek. . .kek. . .kek* (Penteriani 2001), *guck* (Schnell 1958), or *chuuck* (Squires and Reynolds 1997) and will be defined in this paper as the male food-delivery call. Male goshawks use this vocalization frequently throughout the year to facilitate pair contact and prey deliveries (Penteriani 2001). For this reason, and from our field experience where adult females and fledglings seemed very responsive to males giving food-delivery calls (P. Kennedy, unpubl. data), we postulated this call would enhance our ability to detect breeding goshawks using broadcast surveys.

Our objectives were to modify Kennedy and Stahlecker's (1993) broadcast experiment to: (1) test the effectiveness of broadcasting a male food-delivery call, against an adult alarm and juvenile-begging call, for detecting goshawks at occupied nest sites during the breeding season; and (2) provide the first estimate of detection rates of the goshawk subspecies *A. g. laingi* in the dense coastal forests of Vancouver Island, British Columbia, Canada. This subspecies was federally listed in 2000 as Threatened in Canada (Cooper and Chytyk 2000) and Red-listed provincially in 1993 (Ministry of Environment, Lands and Parks 2000).

METHODS

Study Area. Forty goshawk nest areas were located on Vancouver Island, British Columbia between 1994–99 through goshawk inventory efforts and reports by forest company personnel and the public. We conducted broadcast experiment trials at 19 occupied nests within nest areas that were distributed widely throughout Vancouver Island. Nest sites were situated in the coastal western hemlock (CWH; *Tsuga heterophylla*) biogeoclimatic zone, the most productive temperate rainforest region in Canada (Pojar et al. 1991). The dominant tree species were western hemlock and Douglas-fir (*Pseudotsuga menziesii*), although western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*), and red alder (*Alnus rubra*) were also abundant. Vancouver Island has rugged mountains dissected by many creek drainages. Elevations of nest sites ranged from 150–700 m. Mean daily temperatures range from 4.1°C in winter (October–April) to 14.3°C in summer (May–September). Mean monthly precipitation ranges from 40 mm in July to 234 mm in December, with a mean annual total of 1409 mm. Most precipitation falls as rain (Environment Canada 1998).

Broadcast Trials. We conducted broadcast trials at 8 and 11 goshawk nests, respectively, June to mid-August 1998, and April and mid-August 1999. These sample sizes reflect all known occupied (determined during courtship) and active (determined during the nestling and fledgling-dependency phases) goshawk nests on Vancouver Island during these 2 yr. We considered nest areas occupied if females, radio-tagged by other investigations in 1997 and 1998, were present near nest sites or if untagged females were observed or heard vocalizing near nest sites. We considered nests active if nestlings or fledglings were observed. Our definitions of active and occupied are based on McClaren et al. (2002). In both years, we conducted trials during the nestling (June) and fledgling-dependency (early July to early August) stages of goshawk breeding phenology. In 1999 only, we also conducted trials during the courtship period (March to mid-April). We did not conduct broadcast trials during incubation because previous studies demonstrated female raptors were less likely to respond to broadcasts during this period (Fuller and Mosher 1981, Rosenfield et al. 1988), and broadcasts may disturb incubating females and cause egg loss. Also, we only conducted broadcast trials during the initial 25 d of the fledgling-dependency period when fledglings remain within 200–300 m of nests (Kenward et al. 1993, Kennedy et al. 1994). We added active nest sites to the experiment, as they were located, and deleted nest sites when they failed ($N = 2$) because goshawks are less likely to remain near nests after nest failure (Kennedy and Stahlecker 1993). To prevent pseudoreplication and habituation to broadcast calls, broadcast trials in 1999 only occurred at nest sites that held different breeding females than in 1998. We were less concerned about habituation of breeding males to broadcast calls because we expected most detections from the alarm call would be from females (Kennedy and Stahlecker 1993) and because the male food-delivery and juvenile-begging calls target adult females and fledglings.

When we confirmed nests were occupied by females or were active, we established transects following the experimental design of Kennedy and Stahlecker (1993). We spaced eight broadcast stations at 100-m intervals along 700 m transects, using a hip chain to measure distances. Transects were offset perpendicular from nest trees by 100 m to simulate a more realistic survey situation where the probability of transects intersecting nest trees is low (Kennedy and Stahlecker 1993). Thus, the first (farthest from nest tree) and last (closest to nest tree) broadcast stations were 707 m and 100 m from the nest tree, respectively. We oriented transects perpendicular to slopes to minimize topographic interference with sound projection. Most broadcast stations were entirely within the forest to minimize variation in detection abilities and sound projection among habitat types.

We used a commercially available adult goshawk alarm call (Western Bird Songs, Peterson Field Guides, Houghton Mifflin Company, Boston, MA) because we wanted our results to be comparable to other broadcast survey experiments and we wanted to simulate methodology used to locate breeding goshawks throughout North America. Trade name products are mentioned throughout the document to provide complete descriptions of methods. The authors' institutions neither endorse these products nor intend to discriminate against products not mentioned. In the absence of commercially-available recordings, we used a juvenile-begging call recorded by

A.C. Stewart (Ministry of Sustainable Resource Management, Victoria, BC) from Vancouver Island, and a male food-delivery call recorded by M. Robinson from a captive male goshawk in Waterford, Wisconsin. Broadcast calls were professionally recorded onto compact discs (CDs), background noise was removed, and recording levels were standardized so that broadcasting could occur at 100–110 dB (digital sound level meter model 33-2055: InterTan Canada Ltd., Barrie, Ontario, C-weighting [C-weighting is used to measure low frequency sounds that are >85 dB] 1 m from the audio source (Fuller and Mosher 1987) without distortion. We assumed that differences among call types were greater than regional variation within call types.

We used a portable CD player attached via a coaxial cable to a TOA® transistor megaphone (model: SPA-603, TOA Corporation, Kobe, Japan) to broadcast calls. Calls were played from 1-m above ground for 6 calling bouts of 10–12 sec separated by 30 sec of silence. We randomly determined the initial direction of the megaphone, and then rotated 120° to the right or left so that a full 360° was covered twice. We modified Kennedy and Stahlecker's (1993) methods by offsetting a second set of calls 60° from the first to increase the area covered by broadcasts. We also altered their design by following each broadcasting period with 5 min of looking and listening, thus providing 9 min of observation at each broadcast station. This modification was recommended for Vancouver Island by the Resource Inventory Committee (1997) and is consistent with field observations of goshawk detections following shorter broadcast sessions (E. McClaren, unpubl. data). During broadcast trials, E. McClaren recorded all goshawk detections in both years to avoid observer bias. She purposefully and systematically looked and listened in all directions to eliminate detection bias associated with prior knowledge of nest locations. Broadcast trials began at station 1 and were terminated as soon as goshawks were detected. We avoided visiting nests after trials to prevent goshawks from associating us with broadcast calls.

We broadcast adult alarm and male food-delivery calls during the courtship, nestling, and fledgling-dependency periods, whereas we broadcast the juvenile-begging call only during the fledgling-dependency period, when young were sufficiently developed to respond to this call. There were no silent walk-in controls for this experiment because broadcasting conspecific calls has been demonstrated to increase goshawk detection rates (Kennedy and Stahlecker 1993, Watson et al. 1999). Instead, we compared the male food-delivery call to the standard vocalizations used to locate goshawk nests during each breeding phase (Arizona: Joy et al. 1994, Oregon: United States Forest Service 1994, British Columbia: Resource Inventory Committee 1997, Minnesota: Kennedy and Andersen 1999, Alaska: Titus et al. 1999) to see if it enhanced detectability. The alarm call was compared with the male food-delivery call during the courtship and nestling phases. In the fledgling-dependency phase we compared the male food-delivery call with the juvenile-begging call.

We randomized broadcast trials at nests within each breeding stage (courtship, nestling, and fledgling-dependency) and within groups of nests that were geographically close, enabling sampling >1 transect/day. Once broadcast trials were initiated with one call type at a nest site, they were continued every 2 d until all call types were broadcast for that breeding phase. This design prevented differential detection rates from advances in chick development, and minimized temporally correlated detections. Trials were conducted 0800–2000 H; we did not design this experiment to test the influence of time of day on goshawk detection rates. We terminated trials in heavy rain or winds exceeding 20 km/hr. Trials interrupted by weather ($N = 2$) were repeated within 1–2 d

At each broadcast station we recorded date, weather parameters (wind, cloud cover, cloud ceiling, precipitation, temperature), start/end time, detection type (auditory only, visual only, auditory and visual), detection latency (time in sec from start of broadcast session to detection), as well as gender (male, female, unknown) and age (adult, juvenile, unknown) of detected goshawks. We considered goshawk detections between stations ($N = 8$) to be associated with the previous broadcast station. Latencies were calculated from the start of that station's broadcast session until the time of detection.

Statistical Analyses. We evaluated the success of broadcast surveys, relative to broadcast call type and breeding phase, in 3 ways: (1) detection rates; (2) the distance of detections from occupied nests, as this influences the likelihood of locating nest sites; and (3) the probability of detecting a goshawk, with each call type, during each breeding phase. Detection latencies were also analyzed in relation to breeding phase and broadcast call type to determine the optimal amount of time a surveyor should spend at each broadcast station.

Goshawk detection rates were calculated as the number of goshawk detections per number of broadcast trials. We used a chi-square analysis to test for differences in detection rates among broadcast calls and breeding phases. However, this analysis treats broadcast trials conducted at the same nest sites with the same call types in different breeding phases independently, as other studies have done (Kennedy and Stahlecker 1993, Watson et al. 1999). We reanalyzed the data using mixed models, which incorporates the influence of these repeated measures on experimental results. Failure to include repeated measures in models in the following analyses could cause P-values to be inaccurate.

We analyzed the influence of broadcast call type and breeding phase on detection distance (from occupied nests) and detection latency with mixed linear regression models (Littell et al. 1996). Because the experimental design was unbalanced (juvenile-begging calls were only broadcast during one breeding phase in both years, and the courtship phase was tested in only 1 yr), analyses were performed on three data subsets (Table 1). Preliminary analyses provided no evidence that the fixed effects of year, year × broadcast call, and year × breeding phase influenced detection distance (Table 1b [year: $F_{1,6} = 0.01$, $P = 0.94$; year × broadcast call: $F_{1,10} = 0.10$, $P = 0.76$; year × breeding phase: $F_{1,3} = 0.60$, $P = 0.49$]; Table 1c [year: $F_{1,11} = 1.03$, $P = 0.33$; year × broadcast call. $F_{2,15} = 0.31$, $P = 0.74$]). Therefore, we pooled the 1998 and 1999 data except when the courtship phase was included. Fixed effects in mixed linear regression models included breeding phase, broadcast call type, and their interaction. Random effects were nest site and its inter-

Table 1. Three data matrices used in mixed linear and logistic regression models to accommodate an unbalanced experimental design.

CALL TYPE/YEAR	BREEDING PHASE
a) Alarm and male food-delivery calls. 1999	courtship nestling fledgling-dependency
b) Alarm and male food-delivery calls. 1998, 1999	nestling fledgling-dependency
c) Alarm, male food-delivery, and juvenile-begging calls. 1998, 1999	fledgling-dependency

actions with broadcast call type and breeding phase. The term nest site × breeding phase accommodated the influence of repeated transects at the same nest sites (using different call types) within the same breeding phase on experimental results. Likewise, the term nest site × call type incorporated the repeated measures associated with broadcasting alarm and male food-delivery calls during three breeding phases. We square-root transformed detection distances and latencies to decrease the heterogeneity of variances associated with large values. We assessed normality assumptions of mixed linear regression models with studentized residual versus predicted plots and concluded the models in the above analyses were appropriate for the data sets. We compared least square mean detection distances and latencies of broadcast calls within and between breeding phases using pairwise *t*-tests. We did not perform multiple comparison adjustments because comparisons were chosen *a priori* and sample sizes were small. Therefore, we controlled comparison-wise error rates in our analyses.

The influence of broadcast call type and breeding phase on the probability of detecting a goshawk (0 = no detection, 1 = detection) was analyzed using mixed logistic regression models (McCulloch and Searle 2001). We analyzed the three data subsets (Table 1) combining years for analyses that did not include the courtship phase because all year and year interactions were nonsignificant in the previous analyses. As with mixed linear regression models, the fixed effects included broadcast call type, breeding phase, and their interaction. Nest site, the random effect in these models, was used to incorporate variability in detection rates caused by differences in detection probabilities among individual goshawks. Designating nest site as a random effect accommodated problems associated with repeated measures on the same nest sites (sampling the same nest sites using alarm and male food-delivery calls, during three breeding phases). We assumed random effects in mixed logistic models were normally distributed. All analyses were performed using SAS Version 7.0 (SAS Institute 1989).

RESULTS

Detection Rates. Goshawks were detected on 52% of broadcast trials ($N = 88$). In courtship, detection rates were 40% for both the male food-delivery and alarm calls (Table 2). In the nestling phase, detection rates were 60% with the alarm call and 40% with the male food-delivery call, but this difference was not statistically significant ($\chi^2 = 1.20$, $P = 0.27$; Table 2). Detection rates were highest (75%) in the fledgling-dependency phase when the juvenile-begging call was broadcast. However, detection rates were not significantly different among the three call types within this phase ($\chi^2 = 3.56$, $P = 0.17$; Table 2). Goshawks were detected at least once at all but one nest site, after broadcast trials were completed.

For all breeding phases and broadcast calls combined, 83% of goshawk detections were only auditory, 2% were only visual, and 15% were auditory and visual. During the courtship phase (pooled over broadcast call type), all detections were auditory. In the nestling phase, 53% of detections were only auditory and 40% were a combined auditory and visual detection. Detections during the fledgling-dependency phase were primarily auditory

Table 2. Goshawk detection rates (detections/total trials) during broadcast experiments on Vancouver Island, British Columbia, 1998–99.

	BREEDING PHASE			
BROADCAST CALL	COURTSHIP	NESTLING	FLEDGLING-DEPENDENCY	CALL TOTALS
Male food-delivery	2/5	6/15	8/16	16/36
Alarm	2/5	9/15	7/16	18/36
Juvenile-begging	NS[a]	NS	12/16	12/16
Phase totals	4/10	15/30	27/48	46/88

[a] Not sampled.

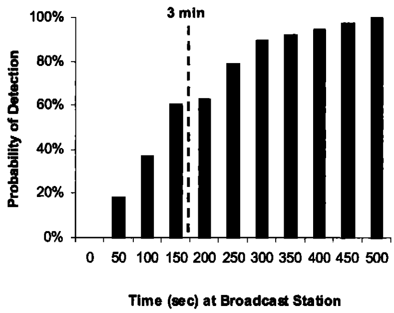

Figure 1. Cumulative probability of detecting goshawks as a function of time spent at broadcast stations during broadcast experiment trials on Vancouver Island, British Columbia, 1998–99. Our study is compared to other studies that spent 3 min at broadcast stations (Kennedy and Stahlecker 1993, Watson et al. 1999).

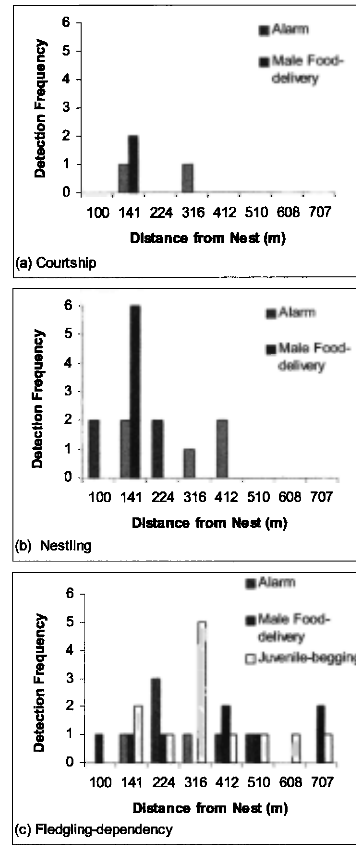

Figure 2. Frequency of goshawk detections as a function of distance from occupied nests, Vancouver Island, British Columbia, 1998–99. Graphs are presented for the (a) courtship, (b) nestling, and (c) fledgling-dependency phases.

only (96%). Similarly, detections for each broadcast call, pooled over breeding phase, were mainly auditory only [male food-delivery call (81%), alarm call (72%), juvenile-begging call (100%)].

Only 39% of detections during broadcast trials were of adult goshawks. During courtship, only adults were available for detection. In the nestling phase, 80% of detections were of adults whereas in the fledgling-dependency phase, 93% of detections were of fledglings. Pooled over breeding phase, the male food-delivery call primarily generated fledgling detections (62%), whereas the alarm call primarily generated adult detections (67%). All detections from the juvenile-begging call were of fledglings.

Detection Latency. We recorded 63% of detections at broadcast stations within 3 min of initiating broadcast calls and 90% of detections within 5 min of initiating broadcast calls (Fig. 1). In other words, 63% of detections occurred after we broadcast three sets of calls and 90% of detections occurred after we broadcast six sets of calls plus a 1 min listening period. Mean detection latencies did not significantly differ between call types within the nestling and fledgling-dependency phases (all pairwise comparison P-values > 0.05).

Detection Distance from Occupied Nests. All detections during the courtship and nestling phases with the male food-delivery call were 141 m from nests (Figs. 2a, 2b). However, in the fledgling-dependency phase we detected goshawks with the male food-delivery call throughout transect distances and as far as 707 m from nests (Fig. 2c). From courtship through fledgling-dependency, goshawks were detected with alarm calls at progressively farther distances from nests. However, greater than 70% of alarm call detections were within 316 m of nests during all breeding phases. With the juvenile-begging call, goshawks were detected 141–707 m from nests but most frequently they were detected at 316 m from nests (Fig. 2c).

Breeding phase influenced the distance we detected goshawks from occupied nests (Fig. 3). The most dramatic pattern we observed was with the male food-delivery call. The mean distance we detected goshawks with the male food-delivery call increased from the courtship ($t = 3.07$, $P = 0.01$) and nestling ($t = 3.64$, $P = 0.003$) phases to the fledgling-dependency phase (Fig. 3). Mean detection distances were similar ($F_{2,17} = 0.79$, $P = 0.47$;

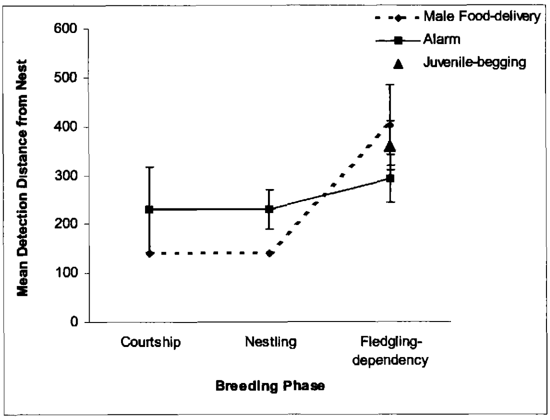

Figure 3. Mean ± SE goshawk detection distance (m) from occupied nests during broadcast experiment trials on Vancouver Island, British Columbia, 1998–99.

Fig. 3) for the three calls in the fledgling-dependency phase.

Detection Probability. The probability of detecting goshawks did not significantly depend on which call type was broadcast within the courtship and nestling phases ($t = -0.28$, $P = 0.78$, $N = 56$), nor did detection probabilities change for a given call type between breeding phases ($t = 0.73$, $P = 0.47$, $N = 56$). However, in the fledgling-dependency phase, broadcasting the juvenile-begging call increased the probability of detecting goshawks relative to alarm and male food-delivery calls ($t = 1.97$, $P = 0.07$, $N = 48$).

DISCUSSION

Efficacy of the Male Food-delivery Call. The probability of detecting goshawks or their young was not increased by broadcasting the male food-delivery call during the courtship, nestling, or fledgling-dependency breeding phases, relative to the standard alarm (courtship, nestling) and juvenile begging (fledgling-dependency) calls. Although not statistically significant, detection rates were higher when alarm and juvenile-begging calls were broadcast during the nestling and fledgling-dependency phases, respectively, relative to broadcasts of the male food-delivery call. Non-statistical differences in our detection rates may reflect small sample sizes as a result of relatively low breeding densities of goshawks on Vancouver Island. However, the 20% and 25% difference in detection rates we observed between the male food-delivery call and alarm and juvenile-begging calls during the nestling and fledgling-dependency phases, respectively, may reflect biologically meaningful differences. Thus, we recommend the continued use of standard calls until a more effective call type is identified.

The male food-delivery call may not be as effective as alarm and juvenile-begging calls in broadcast surveys because it is naturally a call of low pitch and volume that is given by the male when he is delivering food to the nest (Schnell 1958, Squires and Reynolds 1997, Penteriani 2001). Consequently, broadcasting this call at 100–110 dB may be unrealistic and may alter the call's identity. The male's physical presence in the nest stand, as well as his food-delivery call, may stimulate the response. Because this call is used for pair contact, goshawks may utilize individual variation in this call to recognize their mates compared to the alarm and juvenile-begging calls which have more generalized usage. Therefore, when we broadcast a recording from Wisconsin on Vancouver Island, females may have been less responsive to our recording. However, Roberson (2001) later tested the same recording of the male food-delivery call in Minnesota and reported lower detection rates than our study. This suggests that our results are not an artifact of dialect.

Geographic Variation in Detection Rates. Overall, detection rates for alarm and juvenile-begging calls in this study were lower than those reported by Kennedy and Stahlecker (1993). Kimmel and Yahner (1990) and Watson et al. (1999) also reported lower detection rates than Kennedy and Stahlecker (1993). For example, Kennedy and Stahlecker (1993) reported detection rates of 93% with the alarm call during the nestling phase, compared to 60% (this study), 37% (Watson et al. 1999), and 48% (Kimmel and Yahner 1990). Kennedy and Stahlecker (1993) also reported higher detection rates during the fledgling-dependency phase with the juvenile-begging call (85%) than recorded in this experiment (75%) and by Watson et al. (1999; 74%). Regional variation in goshawk detection rates reinforces that local detection probability functions should be incorporated when broadcast data are used to monitor changes in population abundance, elucidate goshawk-habitat relationships, and detect population responses to environmental change.

Lower detection rates in the Pacific Northwest compared to the southwestern United States suggest that transmission of broadcast calls in coastal forests may be hindered by vegetation and topography. These factors may also reduce an observer's ability to detect goshawks, visually and aurally, in coastal forests. Other studies have also expressed, but have not documented experimentally, concerns regarding lower goshawk detection rates with broadcast surveys in coastal forests (southeast Alaska: Iverson et al. 1996; western Oregon: DeStefano and McCloskey 1997; western Washington: Bosakowski and Vaughn 1996). A large body of literature from songbird broadcast experiments documents the scattering of sound by reflective surfaces such as foliage and tree trunks (Fotheringham and Ratcliffe 1995, Brown and Handford 2000). Tree density within goshawk nest areas on Vancouver Island (Ethier 1999) is higher than in New Mexico (Siders and Kennedy 1996) which may degrade broadcast calls. Many songbirds use sound degradation to gauge the distance of an intruder from their territory (Fotheringham and Ratcliffe 1995, Holland et al. 1998). Similarly, goshawks may gauge the distance of broadcast calls and if calls appear far away, they may be less responsive.

Survey Design and the Probability of Detecting a Goshawk. It is important to streamline broadcast surveys so that they occur when they are most effective. Depending on the objective of broadcast surveys, efficacy will be measured by number of detections, number of occupied nests located or both. Breeding phase, call type, distance between broadcast stations and transect lines, and the amount of time spent at each broadcast station will influence the success of broadcast surveys and the amount of time, effort and money expended.

Breeding phase and call type. Detection rates with alarm and male food-delivery calls were similar between the nestling and the fledgling-dependency breeding phases. Our results were similar to conclusions made by Kimmel and Yahner (1990) who broadcast goshawk alarm calls during the nestling and fledgling phases. Conversely, breeding phase influenced the probability of detecting goshawks throughout the breeding season in experiments conducted by Kennedy and Stahlecker (1993). However, they compared differences in combined detection rates from alarm and wail calls during the nestling phase to rates from alarm, wail, and juvenile-begging calls during the fledgling-dependency phase. Thus, it is difficult to ascertain whether Kennedy and Stahlecker (1993) obtained significant results because the effectiveness of individual call types differed between breeding phases or because overall detection rates significantly increased between the nestling and fledgling phases. Total detection rates in our study were also greater in the fledgling-dependency phase compared to the nestling and courtship phases.

Breeding phase influenced the distance goshawks were detected from occupied nests with the mean distance of detection for alarm and male food-delivery calls increasing between the nestling and fledgling-dependency phases. These trends are consistent with other broadcast experiments on goshawks (Kimmel and Yahner 1990, Kennedy and Stahlecker 1993, Watson et al. 1999). Increased mean detection distances with alarm and male food-delivery calls between breeding phases reflects the shift from adults comprising most detections during the courtship and nestling phases, to primarily fledglings during the fledgling-dependency phase. In general, adults are secretive and reveal their presence when intruders or male goshawks are perceived as being close to nests, whereas fledglings often approach observers on transects because male food-delivery (this study), wail (Kennedy and Stahlecker 1993), and juvenile-begging calls (Kennedy and Stahlecker 1993, Watson et al. 1999, this study), probably suggest the likelihood of obtaining food.

Although detection rates were not significantly different among breeding phases in our study, detection rates were 75% in the fledgling-dependency phase, compared with 60% in the nestling phase. However, it is more difficult to locate occupied nests during the fledgling-dependency phase because detections occur farther from nests. To maximize the probability of locating occupied nests, broadcast surveys should be conducted a minimum of twice throughout the breeding season (once during each of the nestling and fledgling-dependency phases). Nest areas should be surveyed a minimum of two consecutive nesting seasons because goshawk nest areas are not always occupied annually (Kennedy and Stahlecker 1993).

Distance between broadcast stations and transect lines. The distances goshawks are detected from active nests influences the optimal spacing of broadcast stations and transect lines. Given that detection rates generally decrease when observers are farther from nests (Kennedy and Stahlecker 1993, Watson et al. 1999, this study), observers are less likely to detect goshawks as the spacing between broadcast stations and transects is increased. Kennedy and

Stahlecker (1993) recommended broadcast stations be located 300-m apart on parallel transects separated from each other by 260 m, and stations on adjacent transects should be offset by 130 m to maximize coverage, because they assumed that goshawk detections were maximum within 100–200 m of occupied nests. Results from this study and Watson et al. (1999) suggest that broadcast surveys in dense, coastal forests could be improved during the nestling phase if broadcast stations and transects are separated by 200 m, with parallel transects being offset from one another by 100 m. Because fledglings are detected at greater distances from nests during the fledgling-dependency phase, broadcast stations and transects conducted during this time could be separated by 400 m to maximize survey efficiency. Staggering adjacent transects by half the distance between broadcast stations maximizes the area covered by calls (Joy et al. 1994).

Time spent at broadcast stations. The time we spent at broadcast stations also appeared to influence our likelihood of detecting goshawks. In our experiment, 37% (N = 14) of detections occurred beyond the 3 min/station practiced by other researchers (Kennedy and Stahlecker 1993, Watson et al. 1999). Our results suggest the optimal amount of time/station is 5 min in dense coastal forests. Sampling for 5 min/broadcast station or six calls plus a 1 min listening period, increases the probability of detecting goshawks at nearby occupied nests, while enabling broadcast surveys to be conducted more efficiently than when observers spend 9 min/station. However, 9 min/station is recommended if surveyors wish to maximize detection probabilities without time constraints.

ACKNOWLEDGMENTS

Forest Renewal British Columbia and the Habitat Conservation Trust Fund provided financial assistance for this research. TimberWest, Weyerhaeuser, Canadian Forest Products, and Western Forest Products reported nest sites, provided funding and enabled this project to run smoothly. D. Doyle secured funding and provided invaluable logistical support. We are grateful to M. Bigg, C. Darimont, D. Klinka, D. Koshowski, S. McDonald, T. Van Enter, K. Wickert, and several others who contributed countless hours of field assistance and reported goshawk nest site locations. M. Baker, B. Van Horne, and K. Wilson offered important study design input and feedback on earlier drafts of this manuscript. T. Bosakowski, G. Hayward, D. Stahlecker, J. Squires, and K. Titus also reviewed an earlier draft of this manuscript and their comments improved the clarity of the manuscript.

LITERATURE CITED

ANDERSON, D.R. 2001. The need to get the basics right in wildlife field studies. *Wildl. Soc. Bull.* 29:1294–1297

BOSAKOWSKI, T. AND D.G. SMITH. 1998. Response of a forest raptor community to broadcasts of heterospecific and conspecific calls during the breeding season. *Can Field-Nat.* 112:198–203.

——— AND M.E. VAUGHN. 1996. Developing a practical method for surveying Northern Goshawks in managed forests of the western Washington Cascades. *West. J. Appl. For.* 11:109–113.

BROWN, T.J. AND P. HANDFORD. 2000. Sound design for vocalizations: quality in the woods, consistency in the fields. *Condor* 102:81–92.

COOPER, J.M. AND P. CHYTYK. 2000. Draft status report on the Queen Charlotte Goshawk *Accipiter gentilis laingi* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON Canada.

CROCKER-BEDFORD, D.C. 1998. The value of demographic and habitat studies in determining the status of Northern Goshawks (*Accipiter gentilis atricapillus*) with special reference to Crocker-Bedford (1990) and Kennedy (1997). *J. Raptor Res.* 32:329–335.

DESTEFANO, S. AND J. MCCLOSKEY. 1997. Does vegetation structure limit the distribution of Northern Goshawks in the Oregon coast ranges? *J. Raptor Res.* 31:34–39.

ENVIRONMENT CANADA. 1998. Canadian climate normals 1961–1990: Campbell River airport, British Columbia Retrieved September 13, 2001 from the World Wide Web: http://www.cmc.ec.gc.ca/climate/normals/BCC002.HTM.

ERWIN, R.M., C.J. CONWAY, AND S.W. HADDEN. 2002. Species occurrence of marsh birds at Cape Cod National Seashore, Massachusetts. *Northeast. Nat.* 9:1–12.

ETHIER, T.J. 1999. Breeding ecology and habitat of Northern Goshawks (*Accipiter gentilis laingi*) on Vancouver Island: a hierarchical approach. M.S. thesis, University of Victoria, Victoria, BC Canada.

FOTHERINGHAM, J.R. AND L. RATCLIFFE. 1995. Song degradation and estimation of acoustic distance in Black-capped Chickadees (*Parus atricapillus*). *Can. J. Zool.* 73:858–868.

FULLER, M.A. AND J.A. MOSHER. 1981. Methods of detecting and counting raptors: a review. *Stud. Avian Biol.* 6. 235–246.

——— AND ———. 1987. Raptor survey techniques. Pages 37–65 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Nat. Wildl. Fed. Sci. Tech. Ser No. 10, Washington, DC U.S.A.

HARDY, P.C. AND M.L. MORRISON. 2000. Factors affecting the detection of Elf Owls and Western Screech-Owls. *Wildl. Soc. Bull.* 28:333–343.

HOLLAND, J., T. DABELSTEEN, AND S.B. PEDERSEN. 1998. Degradation of wren *Troglodytes troglodytes* song: implications for information transfer and ranging. *J. Acoust. Soc. Am.* 103:2154–2166.

IVERSON, G.C., G.D. HAYWARD, K. TITUS, E. DEGAYNER, R.E. LOWELL, D.C. CROCKER-BEDFORD, P.F. SCHEMPF, AND J. LINDELL. 1996. Conservation assessment for the Northern Goshawk in southeast Alaska. Gen. Tech. Rep. PNW-GTR-387, USDA, USFS, Pacific Northwest Research Station, Portland, OR U.S.A.

JOY, S.M., R.T. REYNOLDS, AND D.G. LESLIE. 1994. Northern Goshawk broadcast surveys: hawk response variables and survey costs. *Stud. Avian Biol.* 16:24–30.

KENNEDY, P.L. 1998. Evaluating Northern Goshawk (*Accipiter gentilis atricapillus*) population trends: a reply to Smallwood and Crocker-Bedford. *J. Raptor Res.* 32: 336–341.

——— AND D.E. ANDERSEN. 1999. Research and monitoring plan for Northern Goshawks (*Accipiter gentilis atricapillus*) in the Western Great Lakes Region. Retrieved March 29, 2000 from the World Wide Web: http://www.fw.umn.edu/CO-OP/download/default.html.

——— AND D.W. STAHLECKER. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of 3 conspecific calls. *J. Wildl. Manage.* 57:249–257.

———, J.M. WARD, G.A. RINKER, AND J.A. GESSAMAN. 1994. Post-fledgling areas in Northern Goshawk home ranges. *J. Avian Biol.* 16:75–82.

KENWARD, R.E., V. MARCSTROM, AND M. KARLBOM. 1993. Post-nesting behaviour in goshawks, *Accipiter gentilis*: I. The causes of dispersal. *Anim. Behav.* 46:365–370.

KIMMEL, J.T. AND R.H. YAHNER. 1990. Response of Northern Goshawks to taped conspecific and Great Horned Owl calls. *J. Raptor Res.* 24:107–112.

LEGARE, M.L., W.R. EDDLEMAN, P.A. BUCKLEY, AND K. COLLEEN. 1999. The effectiveness of tape playback in estimating Black Rail density. *J. Wildl. Manage.* 63:116–125.

LITTELL, R.C., G.A. MILLIKEN, W.W. STROUP, AND R.D. WOLFINGER. 1996. SAS system for mixed models. SAS Institute, Cary, NC U.S.A.

MCCLAREN, E.L. 2001. Factors influencing Northern Goshawk detectability and reproduction on Vancouver Island, British Columbia. M.S. thesis, Colorado State University, Fort Collins, CO U.S.A.

MCCLAREN, E.L., P.L. KENNEDY, AND S.R. DEWEY. 2002. Do some Northern Goshawk nest areas fledge more young than others? *Condor* 104:343–352.

MCCULLOCH, C.E. AND S.R. SEARLE. 2001. Generalized, linear, and mixed models. Wiley Series in Probability and Statistics. John Wiley and Sons, Inc., New York, NY U.S.A.

MCLEOD, M. AND D.E. ANDERSEN. 1998. Red-shouldered Hawk broadcast surveys: factors affecting detection of responses and population trends. *J. Wildl. Manage.* 62: 1385–1397.

MINISTRY OF ENVIRONMENT, LANDS AND PARKS. 2000. 2000 Red and Blue lists for amphibians, reptiles, birds and mammals. Victoria, BC Canada.

MOSHER, J.A. AND M.R. FULLER. 1996. Surveying woodland hawks with broadcasts of Great Horned Owl vocalizations. *Wildl. Soc. Bull.* 24:531–536.

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.

PENTERIANI, V. 2001. The annual and diel cycles of goshawk vocalizations at nest sites. *J. Raptor Res.* 35:24–30.

POJAR, J.E., K. KLINKA, AND D.A. DEMARCHI. 1991. Coastal western hemlock biogeoclimatic zone. Pages 95–112 *in* D.V. Meidinger and J.E. Pojar [EDS.], Ecosystems of British Columbia. Spec. Rep. Ser. No. 6. British Columbia Ministry of Forests Research Branch, Victoria, BC Canada.

REID, J.A., R.B. HORN, AND E.D. FORSMAN. 1999. Detection rates of Spotted Owls based on acoustic-lure and live-lure surveys. *Wildl. Soc. Bull.* 27:986–990.

RESOURCE INVENTORY COMMITTEE. 1997. Standard inventory methodologies for components of British Columbia's biodiversity: raptors. Version 1.1. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC Canada.

ROBERSON, A.M. 2001. Evaluating and developing survey techniques using broadcast conspecific calls for Northern Goshawks in Minnesota. M.S. thesis, University of Minnesota, St. Paul, MN U.S.A.

ROSENFIELD, R.N., J. BIELEFELDT, AND R.K. ANDERSON 1988. Effectiveness of broadcast calls for detecting breeding Cooper's Hawks. *Wildl. Soc. Bull.* 16:210–212.

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.

SAS INSTITUTE. 1989. SAS/STAT user's guide. Version 6.12. Fourth Ed. SAS Institute, Cary, NC U.S.A.

SCHNELL, J.H. 1958. Nesting behavior and food habits of goshawks in the Sierra Nevada of California. *Condor* 60:377–403.

SIDERS, M.S. AND P.L. KENNEDY. 1996. Forest structural characteristics of *Accipiter* nesting habitat: is there an allometric relationship? *Condor* 98:123–132.

SMALLWOOD, K.S. 1998. On the evidence needed for listing Northern Goshawks (*Accipiter gentilis*) under the Endangered Species Act: a reply to Kennedy. *J. Raptor Res.* 32:323–329.

SMITH, G.C. AND D.N. JONES. 1997. Vocalisations of the marbled frogmouth I: descriptions and analysis of sex differences. *Emu* 97:290–295.

SQUIRES, J.R. AND R.T. REYNOLDS. 1997. Northern Goshawk (*Accipiter gentilis*). Pages 1–32 *in* A. Poole and F. Gill [EDS.], The Birds of North America, No. 298. The Academy of Natural Sciences, Philadelphia, PA U.S.A., and The American Ornithologists' Union, Washington, DC U.S.A.

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

TITUS, K., C. FLATTEN, AND R. LOWELL. 1999. Goshawk ecology and habitat relationships on the Tongass National Forest. 1998 annual report. Study SE-4-2. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK U.S.A.

UNITED STATES FOREST SERVICE. 1994. Goshawk monitoring, management, and research in the Pacific Northwest region: 1994 status report. USDA, USFS, Portland, OR U.S.A.

WATSON, J.W., D.W. HAYS, AND D.J. PIERCE. 1999. Efficacy of Northern Goshawk broadcast surveys in Washington State. *J. Wildl. Manage.* 63:98–106.

Received 15 July 2002; accepted 21 April 2003