EFFICACY OF NORTHERN GOSHAWK BROADCAST SURVEYS IN WASHINGTON STATE

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Abstract: Statewide surveys conducted for northern goshawks (*Accipiter gentilis*) by the Washington Department of Fish and Wildlife (WDFW) in the early 1990s had relatively low detection rates throughout the state and different rates of detection between eastern (1 bird/55 km) and western Washington (1 bird/174 km). To investigate the possibility that survey methods or regional habitat characteristics affected detection rates, we tested broadcast calls at 40 nest stands known to be occupied by nesting northern goshawks. During 439 station visits and 210 trials, we recorded 109 detections, 68% of which were vocalizations. Northern goshawks at 37 of the 40 (93%) occupied territories were detected at least once, including 4 occupied sites that failed. Detectability was greater at successful nests. Juvenile northern goshawks were more responsive than adults, which increased detection rates at successful nests by 37% during the postfledging period and accounted for 87% of responses. Logistic regression modeling identified distance of the surveyor to the nest as the only factor correlated with detection rates ($P < 0.001$). Probability of detecting northern goshawks at occupied stands increased as nests were approached from 400 m (0.20), 250 m (0.25), and 100 m (0.42). Binomial expansion of detection probabilities at a single nest visit found broadcasting to attain ≥90% detections required 5 visits at 100 m, 8 at 250 m, and 10 at 400 m. Because analysis of detection rates by area did not show an effect of vegetation screening, slope, or topography, differences in the relative abundance of northern goshawks from earlier surveys reflect true variation in abundance, differences in nest success, or some combination of both. Results lend more justification for use of broadcast calling for northern goshawks in Pacific Northwest forests and provide a hypothetical model for estimating survey costs as a function of detection probability, trial frequency, and station spacing.

JOURNAL OF WILDLIFE MANAGEMENT 63(1):98–106

Key words: *Accipiter gentilis*, broadcast call, northern goshawk, population status, raptor survey, Washington.

Broadcasts of recorded vocalizations are often used to detect woodland raptors. In the past 2 decades, this method has been developed to locate owls (Nowicki 1974, Beatty 1977, Forsman et al. 1984, McGarigal and Fraser 1985), and, more recently, diurnal raptors, principally accipiters (Rosenfield et al. 1988, Kimmel and Yahner 1990, Mosher et al. 1990, Kennedy and Stahlecker 1993, Mosher and Fuller 1996). The technique has been used to identify nest locations and to detect presence or absence of species (Fuller and Mosher 1987), and to estimate population parameters such as density and relative abundance (Mosher et al. 1990, Iverson and Fuller 1991, Mosher and Fuller 1996). Such applications necessitate evaluating and refining the effectiveness of the technique (McGarigal and Fraser 1985, Rosenfield et al. 1988, Kennedy and Stahlecker 1993).

The status of northern goshawks in the western United States is currently of interest on state, federal, and private forest lands. Because adult northern goshawks are secretive and their nests are relatively difficult to locate in forested habitats, broadcast of conspecific vocalizations has been the most effective method used to detect them (Kimmel and Yahner 1990, Kennedy and Stahlecker 1993, Joy et al. 1994).

In 1993 and 1994, we surveyed random transects for northern goshawks in eastern and western Washington via the methodology of Kennedy and Stahlecker (1993). Analysis of the survey data found greater northern goshawk response rates in eastern Washington (1 bird/55 km of transects) compared to the dense forests of western Washington (1 bird/174 km of transects; WDFW, unpublished data). However, the effectiveness of this survey method has not been assessed in Washington and in other western coniferous forests. Effects of sources of var-

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iability on survey results (i.e., vegetation screening and topography) might be especially relevant in western coniferous forests. These factors might conceal surveyors from territorial adults, thereby reducing response rates. Northern goshawk broadcast calls also may be attenuated by vegetation type and structure (P. F. Schempf, U.S. Fish and Wildlife Service, personal communication), and responses may be affected by nest stage (i.e., nestling or postfledge period) and distance of the surveyor from the nest (Kennedy and Stahlecker 1993). Our objectives were (1) evaluate effectiveness of the Kennedy and Stahlecker (1993) broadcast survey technique at active northern goshawk nests in eastern and western Washington, (2) evaluate the influence of vegetation screening and topography on northern goshawk responses, and (3) identify other factors influencing northern goshawk detection.

STUDY AREA

We attempted to locate ≥20 active northern goshawk nests in eastern and western Washington by visiting historic nests (Wildlife Resource Data System, Heritage Data Base, WDFW), using information from ongoing northern goshawk studies (S. Finn, Boise State University, personal communication), and investigating sightings by falconers. We conducted searches in western Washington in the Olympic Mountains, west Cascades, and north Cascades, and in the east Cascades in central Washington (Fig. 1).

Northern goshawk nests in western Washington were in temperate forests of mixed conifers (Franklin and Dyrness 1973) dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). In this region, breeding northern goshawks nest from sea level to 1,200 m (WDFW, unpublished data). Forests in eastern Washington were mixed-conifer stands (Franklin and Dyrness 1973) dominated by pondersa pine (*Pinus ponderosa*), Douglas-fir, and grand fir (*Abies grandis*). Northern goshawks nest ≤1,500 m in elevation along the eastern slope of the Cascades (WDFW, unpublished data).

METHODS

Surveys

We conducted nest searches from May through June. When ≥1 adult was located in a nest stand, we classified the stand as occupied and initiated monitoring to identify nests and determine initiation of incubation. We visited nests ≤1 time/week to minimize disturbance to the birds. We established a 387-m transect beginning 400 m from the nest tree (Station 1) and tangential to a 100-m radius from the nest tree (Station 2) because survey approaches tangential to nests are probably more common than direct approaches (Kennedy and Stahlecker 1993). The location from which the first broadcast was made was selected randomly within the limitations imposed by topography (i.e., not across major drainages, cliff faces, etc.). We assessed vegetation screening from the transect to the nest by recording nest visibility at each station (totally visible, partially visible, not visible). Slope of the terrain from the transect to the nest was also recorded (uphill, level, downhill), as was topographical interference to the nest (present, absent).

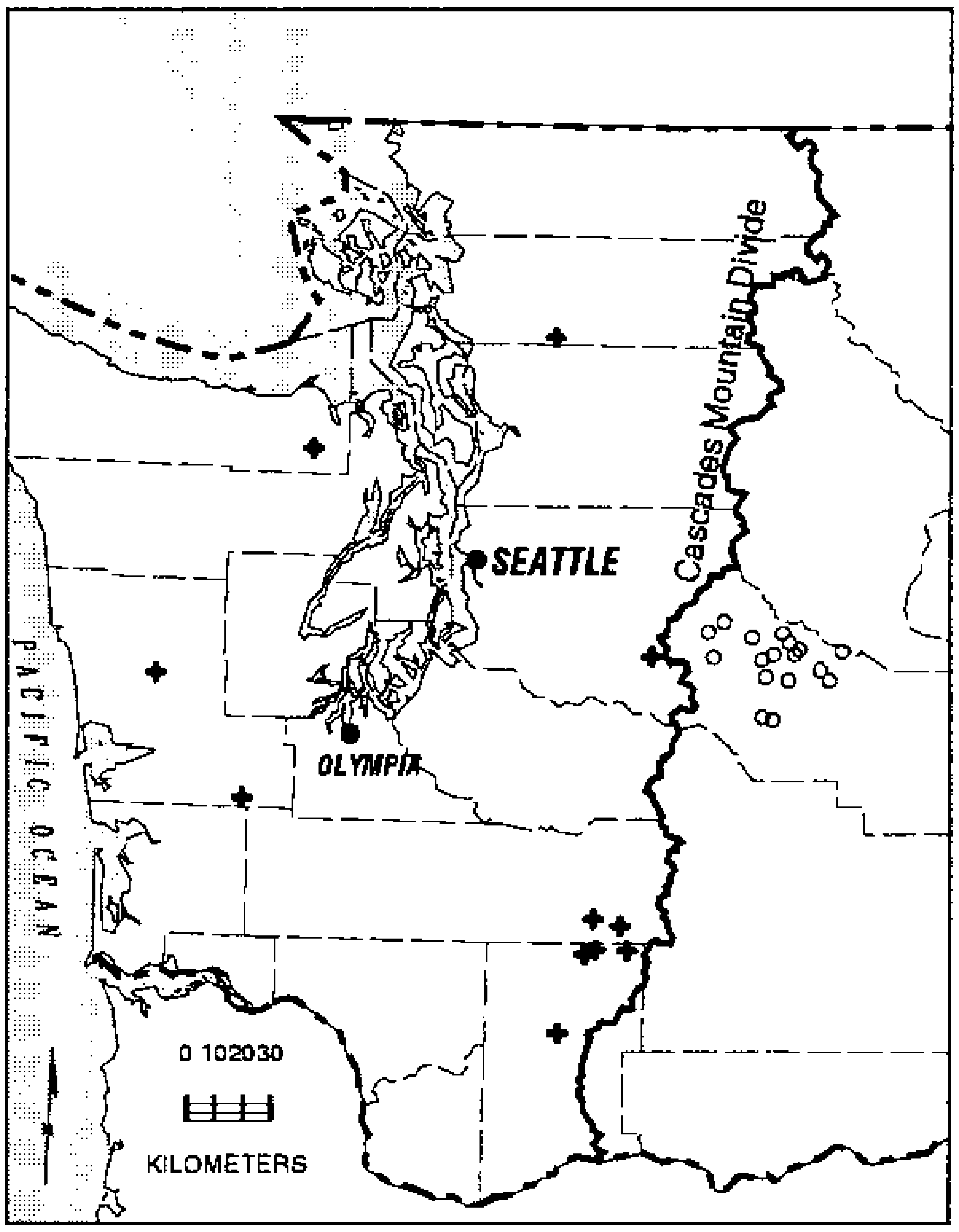

Fig. 1. Locations of northern goshawk nests sampled during the experimental survey study in eastern (○) and western (+) Washington, 1995–96.

We did not initiate control and broadcast trials during the courtship period, because northern goshawk activity at nesting areas was generally not confirmed until adults were incubating. We did not conduct trials during incubation, because preliminary observations indicated incubating adults were virtually unresponsive to observer presence, even in close proximity to nests. We began trials when adults first brooded young, or on the hatching date, which was predicted from a 31-day incubation period (i.e., 30–32 days; Reynolds and Wight 1978) from the first day we observed incubating adults. Control trials consisted of a surveyor standing at the first station, slowly scanning 360° for visual or auditory detections of northern goshawks, and moving to the second station after 3 min. Trials ended when a northern goshawk was detected or after completing the second station.

We returned to the nest 2 days later and conducted broadcast trials during which time the surveyor played a recorded northern goshawk alarm call (nestling period) or juvenile food-beg call (postfledging period). We determined the presence of fledged juveniles by periodic checks of the nest before conducting control or broadcast trials. Broadcast tapes were supplied by the U.S. Forest Service, Southwest Region. Calls were broadcast from a portable tape player and megaphone (Wildlife Callers, Bellevue, Washington, USA); to protect the hearing of surveyors, each unit was standardized prior to the study to an output of about 85 dB.

Trials began at the first station to minimize pretrial disturbance to birds. Following the protocol of Kennedy and Stahlecker (1993), the initial call was directed 60° from the transect, then 180°, and then 300°. The surveyor looked and listened for 30 sec prior to the first broadcast and following the first 2 broadcasts, and for 60 sec after the third broadcast (total = 3 min/station). For successful nests (i.e., ≥1 young present), we conducted a minimum of 2 experiments (i.e., 2 control trials, 2 broadcast trials) during the nestling period and 2 experiments during the postfledging period. For failed nests, 2 experiments were conducted in the nestling period. To verify nest failure, nest checks and nonexperimental broadcasts were conducted later during the postfledging period.

To reduce the effect of weather conditions on detectability, we did not conduct trials during heavy rain or on days when the Beaufort wind scale was ≥3 (i.e., small twigs in motion, small ground debris moving, some sway of larger trees). All trials began after 0800 and were completed before 1600.

When we detected northern goshawks, we recorded type of detection (vocal only, visual only, vocal and visual, attack), duration of response (<10 sec, 11–60 sec, >60 sec), closest station to the response, distance of the surveyor to the nest, estimated distance of the surveyor to the responding bird, and age of the responding bird (juvenile, adult, unknown). Distance of the responding bird to the surveyor was estimated to the nearest 50 m because birds often were not visible. We used a pictoral guide to estimate ages of young within 2–3 days (Boal 1994).

We made changes to the data collection protocol in 1996. To refine estimates of response distance, we added a 250-m station between Stations 1 and 2. Because analysis of 1995 responses identified a significant effect of broadcasting on northern goshawk detections, we discontinued control trials in 1996.

Statistical Analyses

Frequency of detections versus no detections was pooled for trials and compared among levels of trial type, year, nest stage, region, and slope with chi-square contingency tests. We also used contingency tests to compare occupancy rates (sites occupied by ≥1 adult vs. unoccupied) by area, call type by nest success, nest stage, distance to the responding northern goshawk, and nest stage and call duration. Area comparisons of incubation dates were conducted with 2-sample *t*-tests. We reported means ± standard deviation.

Because of the difficulty in locating active nests to sample, we treated nests active both years as independent samples. We treated trials at each nest as independent replicates, but, as noted by Kennedy and Stahlecker (1993), these trials were not truly independent. Ideally, trials should have been conducted at 1 station (i.e., distance) on a given day to assure independence of response. However, this protocol was impractical because of the time and effort necessary to access many nests (i.e., >3 hr), and because our main objective was to duplicate and assess the earlier statewide survey effort in Washington. The effect of distance on detection, which was assessed by station, was the factor potentially influenced by nonindependence. To address the issue of independence as it related distance analyses, we summarized the number of visits to each station and reported the percentage of nest sites where northern goshawks responded at the same or different stations. We estimated detection rates (response frequency/total no. of station visits) in 2 ways: (1) the response frequency at the distance when the bird responded and the trial terminated;

and (2) the cumulative response frequency, which assumed northern goshawks would have responded at all closer distances (i.e., 250 m, 100 m) given the opportunity (Stalmaster and Newman 1978, Knight and Knight 1984, McGarigal et al. 1991). The latter method generated maximum estimates of response rates (McGarigal et al. 1991) and was not affected by station independence. Point estimates for cumulative rates were appropriate for use in regression analyses (Diggle et al. 1996), although confidence intervals were not interpretable and therefore are not reported. We used logistic regression (PROC CATMOD; SAS Institute 1989) to estimate relations of distance, geographic area, and slope to detection rates (cumulative, noncumulative) at occupied nests. We identified the best models via the Akaike Information Criterion (AIC; SAS Institute 1989).

Using the approach of Gibbs and Melvin (1993), we estimated the probability of detecting northern goshawks during a single visit to successful nests. Binomial expansion (Zar 1984) of the detection probability for the distance effect was used to assess changes in detection probabilities as a function of nest visits (i.e., trials). We estimated the cost of surveying a 100,000-ha forest, at different probabilities of detection, as a function of trial frequency and station spacing. Survey cost was estimated by multiplying the cost/station (personnel cost per season/no. stations potentially called per season) by the number of stations required to sample the forest via staggered, parallel transects (Joy et al. 1984).

RESULTS

Nest Success and Nest Phenology

We conducted experiments at 17 northern goshawk nest stands in 1995 and 23 in 1996. We sampled 16 nest stands during 1 year, but we sampled 5 nest stands west of the Cascade Crest and 7 nest stands on the east side during both years. Northern goshawks at 36 (90%) of 40 occupied nest stands nested successfully (fledged ≥1 young), 2 pairs (5%) nested unsuccessfully, and 2 pairs (5%) did not attempt to nest. Searches of historical northern goshawk nest stands were conducted at 64 sites on the west side and 11 additional sites on the east side during the 2-year study. The occupancy rate of all northern goshawk nest stands surveyed for combined years was 38% (n = 137). Occupancy at east side nest stands (61%) was greater than occupancy on the west side (28%; $\chi^2_1 = 12.98$, $P = 0.001$), and occupancy in the western Cascades (40%) was greater than in the Olympic Range (21%; $\chi^2_1 = 3.95$, $P = 0.047$).

Northern goshawks initiated incubation between the last week of April and first week of May (mean laying date = 29 April ± 10 days, $n = 36$). Average incubation date on the east side (26 Apr ± 7 days) was earlier ($t_{32} = 2.55$, $P = 0.016$) than on the west side (4 May ± 11 days). Northern goshawks on the Olympic Peninsula tended to nest earlier (mean laying date = 22 Apr ± 8 days) than those in the western Cascades (mean laying date = 8 May ± 9 days; $t_5 = 2.15$, $P = 0.084$). Average estimated age of young during trials was 23 ± 11 days ($n = 250$) during the nestling stage and 59 ± 14 days ($n = 221$) for the postfledging stage.

Detection Rates

For 210 broadcast and control trials from combined years, we recorded 109 northern goshawk detections during 439 station visits, which resulted in a detection rate of 51.9%/trial and 24.8%/station. There was ≥1 detection at 37 of the 40 (93%) occupied nest stands. Birds were detected ≥1 time at 3 of the 4 (75%) occupied sites that failed. These failures occurred during the nestling period in 1995, and no detections were recorded in the postfledging period. Northern goshawks were detected at 34 of 36 (94%) successful sites. Of 109 detections, 68% were vocalizations only, and the remainder were vocal and visual (24%), visual only (6%), and attacks on the surveyor (3%).

Factors Influencing Detection

We conducted 62 experiments at 17 occupied northern goshawk nest stands (9 east side, 8 west side) in 1995 to determine the effects of trial type (broadcast vs. no broadcast) on detection rates. Broadcast calling increased ($P = 0.001$) detection rates for all occupied nest stands combined (Table 1), but northern goshawk detection rates at 4 occupied nests that failed were the same ($P = 0.122$) for control (6.3%) and broadcast trials (25.0%). For successful nests, use of broadcast calls for detecting hawks was more effective than nonvocal surveys (i.e., controls) in the nestling period ($\chi^2_1 = 4.79$, $P = 0.029$) compared to the postfledging period ($\chi^2_1 = 13.82$, $P = 0.051$). During the former period, we detected northern goshawks on

Table 1. Detection rates of northern goshawks at occupied nest stands (i.e., ≥1 adult present) among different levels of independent variables measured during broadcast surveys in Washington.

Variable	Variable level	Trials[a] (*n*)	Detections (*n*)	Detection rate[b]	χ^2	df	*P*
Trial type[c]	Control	62	19	30.7	10.56	1	0.001
	Broadcast	62	37	59.7			
Year	1995	62	37	59.7	0.06	1	0.810
	1996	86	53	61.6			
Nest stage	Nestling	75	43	57.3	0.77	1	0.380
	Postfledge	73	47	64.4			
Region	East side	82	46	56.1	1.71	1	0.190
	West side	66	44	66.7			
Terrain slope	Uphill	116	71	61.2	3.20	2	0.202
	Level	4	4	100.0			
	Downhill	28	15	53.6			

[a] All trials were broadcasts, except for control trials in trial type comparisons.

[b] Number of detections/number of trials.

[c] Includes paired comparisons conducted only in 1995.

14.3% of 35 control days and 37.1% of 35 broadcast days. During the postfledging period, we detected northern goshawks on 48.1% of 27 control days and 74.1% of 27 broadcast days.

We did not find annual differences in detection rates for all occupied nests (Table 1). Thus, data for broadcast trials were pooled from 1995 and 1996 to identify factors affecting detection rates at successful nests. Nest stage did not affect detection rates, although rates were 7.1% greater in the postfledging period compared to the nestling period (Table 1). Detection rates at occupied nests in western Washington were 10.6% greater than in eastern Washington, but the difference was not statistically different ($P = 0.190$; Table 1). Slope of the terrain from survey transects to the nest did not influence detection rates (Table 1). All nests were completely screened from the survey transect (i.e., 100% of all stations), so testing of this factor was precluded by lack of variability. Topography was dropped as an analysis variable after 1995 because it was correlated with vegetation screening (Spearman rank correlation: $r^2 = 0.987$, $P = 0.005$).

For occupied nests, distance to the nest was inversely related to the detection rate (Table 2). Detection rates at 100 m were 21.6% greater than at 250 m and 23.4% greater than 400 m. Distance was also inversely related to the cumulative detection rate (Table 2). Cumulative detection rates at 100 m were 22.4% greater than at 250 m and 40.5% greater than 400 m. Mean distance of the surveyor to the nest at the point of detection was 265 ± 123 m ($n = 90$).

Distance between the surveyor and the northern goshawk at the point of response was different between nestling and postfledging periods ($\chi^2_8 = 19.06$, $P = 0.015$). During the nestling period, 80% of detections were ≤100 m from northern goshawks, compared to 47% during postfledging. Most (88.4%) detections during the nestling period were of adults, whereas 87.2% of detections during the postfledging period were of juveniles. Response duration also varied by nest stage ($\chi^2_1 = 3.92$, $P = 0.048$).

Table 2. Effect of distance on detection rates of northern goshawks at occupied nest stands (i.e., ≥1 adult present) responding to broadcast surveys in Washington. Incremental detection rate = total number of responses/total number of station visits. Cumulative detection rate is based on the sum of all responses greater than a given distance.

Response type	Distance from nest (m)	No. station visits			No. responses			Detection rate	χ^2	df	*P*
		1995	1996	Total	1995	1996	Total				
Incremental	100	50	53	103	25	20	45	43.7	18.06	2	0.001
	250		68	68		15	15	22.1			
	400	62	86	148	12	18	30	20.3			
Cumulative	100	62	86	148	37	53	90	60.8	50.78	2	0.001
	250		86	86		33	33	38.4			
	400	62	86	148	12	18	30	20.3			

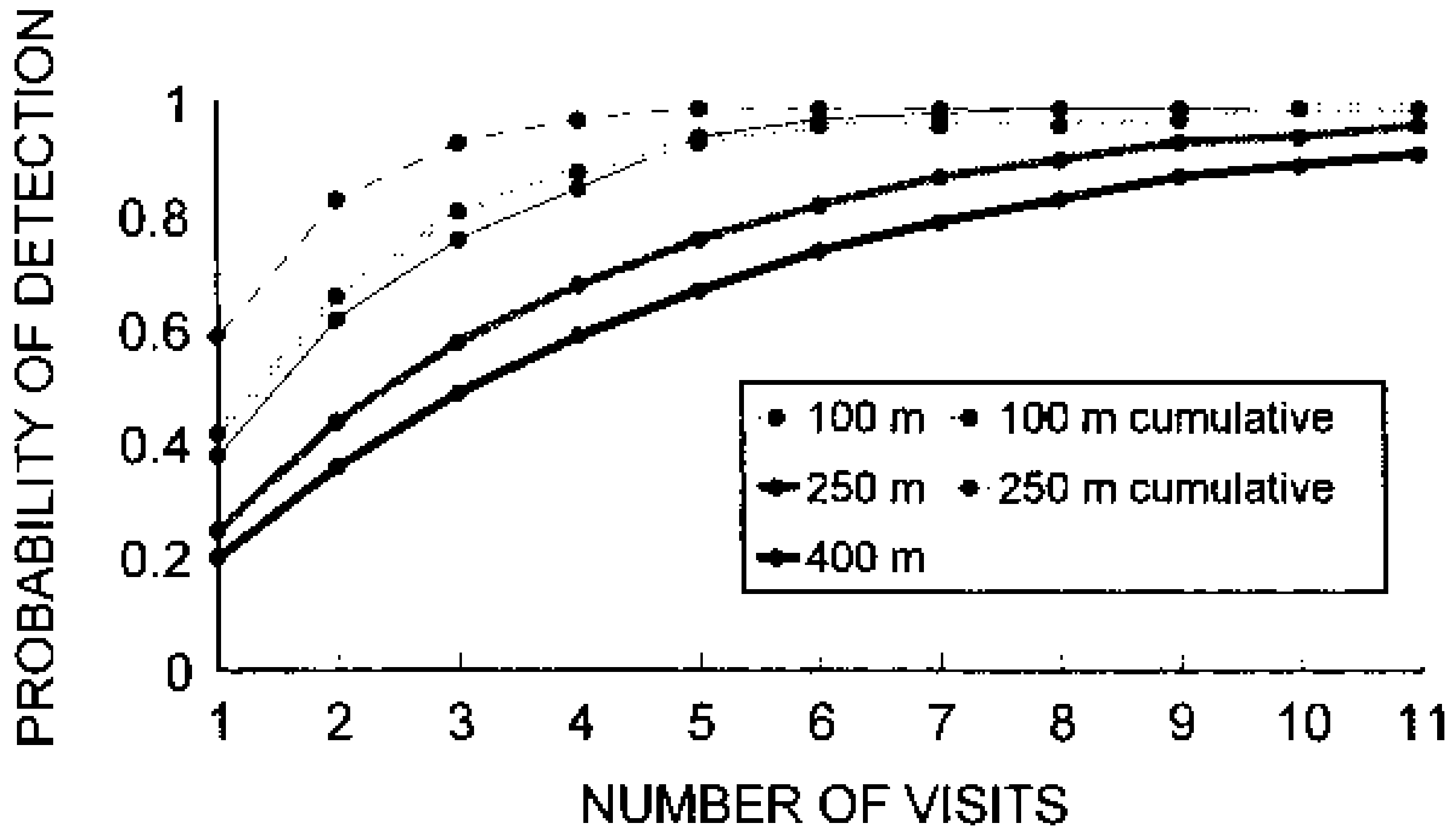

Fig. 2. Estimated probability of detecting northern goshawks at successful nests during multiple visits with varied spacing of call stations, Washington 1995–96. Cumulative rates are projections based on the assumption that northern goshawks would have responded at all closer stations had the trial not terminated at first response.

Responses >60 sec long composed 32.6% of detections during the nestling period but 61.7% during the postfledging period. During the nestling period, adult northern goshawks tended to call briefly and approach surveyors closely or attack them, while fledged juveniles often responded vocally for several seconds, but without approaching surveyors.

Interactive Effects

Data Independence.—We conducted an average of 3.7 ± 0.8 trials/nest (mode = 4) and 3.2 ± 1.1 visits/station (mode = 4). For the 33 nest sites where northern goshawks responded at >1 station, 39% were at the same station ($\bar{x}$ = 2.7 ± 1.1 responses, mode = 2), and 61% were at different stations ($\bar{x}$ = 3.5 ± 1.6 responses, mode = 3). Thus, for ≥3 responses at a nest, northern goshawks tended to respond at the different stations for different trials.

Logistic Regression.—Distance was the single factor correlated with detection rates at occupied nests (n = 40) when we modeled the probability of no detection with interactive effects (estimated intercept = −0.030, SE = 0.268; χ^2_1 = 0.01, P = 0.911; estimated distance effect = 0.004, SE = 0.001; χ^2_1 = 14.96, P < 0.001). No interactive effects were significant. Distance was the single factor correlated with cumulative detection rates at occupied nests according to the logistic regression model for interactive effects (estimated intercept = −1.041, SE = 0.230; χ^2_1 = 20.47, P < 0.001; estimated distance effect = 0.006, SE = 0.001; χ^2_1 = 47.10, P < 0.001). No interactive effects were significant.

Table 3. Estimated personnel cost[a] (in thousands of dollars) associated with broadcast surveys for northern goshawks across a 100,000-ha forest, with varying efficiency due to spacing of stations and survey frequency. The entire forest is presumed to be accessible, potential habitat. About 100 survey days/season are available to complete trials. Detection probabilities are conservative estimates.

Station spacing[b] (m)	Trial frequency				
	1	2	3	4	5
200	140[c]	280[d]	420[e]	560[e]	700[f]
500	22[c]	45[c]	67[c]	89[d]	112[e]
800	9[c]	18[c]	27[c]	36[c]	45[d]

[a] Based on personnel cost of $12.00/hr. calling 1 station/15 min. 20 stations/day (5 of 8 hr surveying). 75 days/season (mid-May–Aug); hence, 1,500 stations·person^{-1}·season^{-1}, or $4.80/station. The 200-m spacing will require 29,249 calling stations (i.e., 19.5 surveyors/trial), the 500-m spacing will require 4,674 stations (i.e., 3.1 surveyors/trial), and 800-m spacing will require 1,825 stations (i.e., 1.2 surveyors/trial).

[b] Spacing based on response rates at stations 100, 250, and 400 m from nests (Fig. 2). To maximize efficiency, staggered, parallel transects (Joy et al. 1994) are spaced at 173 m, for 100-m spacing, 433 m for 250-m spacing, and 693 m for 400-m spacing.

[c] <60% detection probability.

[d] 60%–74% detection probability.

[e] 75%–89% detection probability.

[f] ≥90% detection probability.

Predicting Detection at Occupied Nests

The probability of detecting a northern goshawk during a single visit to an occupied nest stand was estimated for nonbroadcast surveys (0.28; 95% CI = 0.12–0.44, n = 17 nest stands) and broadcast surveys (0.58; 95% CI = 0.45–0.72, n = 17 nest stands); for broadcast surveys in eastern Washington (0.54; 95% CI = 0.41–0.67, n = 24 nest stands), and western Washington (0.67; 95% CI = 0.57–0.77, n = 16 nest stands); and for broadcast surveys 100 m from nests (0.42; 95% CI = 0.31–0.53, n = 40 nest stands), 250 m from nests (0.25; 95% CI = 0.10–0.39, n = 24 nest stands), and 400 m from nests (0.20; 95% CI = 0.13–0.27, n = 40 nest stands). The probability of detecting a northern goshawk in a nest stand 100 m from the nest, based on cumulative response rates, was 0.59 (n = 40 nest stands). The probability of detection was 0.38 at 250 m from the nest (n = 24 nest stands).

Predicted detection during multiple visits to nests was different, depending on the spacing of stations (Fig. 2). Broadcasts to attain 90% detection required 5 visits for stations spaced at 100 m, 8 visits for 250-m spacing, and 10 visits at 400-m spacing. Estimated detection rates based on cumulative responses were 10% higher for each visit at 100 m, and 20% higher at 250 m (Fig. 2). Cost estimates to broadcast survey for nesting northern goshawks within a 100,000-ha forest ranged from $9,000 to

$700,000, depending on the desired probability of detection, station spacing, and trial frequency (Table 3). Detection probabilities were conservative because they did not account for the fact that the same bird could be detected at >1 station.

DISCUSSION

Our ability to detect northern goshawks at known, occupied nests in Washington state was not related to their occurrence in east side rather than west side forests. From a broad-based perspective of forest and understory characteristics in these areas, we hypothesized that increased vegetation and topographical interference might explain the lower detection rates of west side northern goshawks as recorded in previous random surveys (WDFW, unpublished data) where there was no knowledge of nest sites. Dense understory vegetation and topography would be expected to reduce the visibility of northern goshawks to the surveyor and increase the rate of attenuation of the broadcast calls before they were perceived by the northern goshawk. Experiments in northern goshawk habitat in Southeast Alaska found attenuation of northern goshawk broadcast calls due to vegetation type and structure (P. F. Schempf, U.S. Fish and Wildlife Service, personal communication). We found that 100% of call stations in both geographic areas were screened from view, and that topography and slope did not influence detection rates.

The lack of effect of geographic area suggests the regional difference in detections of nesting northern goshawks identified during previous surveys was indicative of actual differences in relative abundance, and presumably northern goshawk population size. Random broadcast surveys to locate nesting northern goshawks in the temperate rain forests of Southeast Alaska found responses were 7–9 times lower than in the open, conifer forests in the Rocky Mountain region of Arizona and Idaho (P. F. Schempf, U.S. Fish and Wildlife Service, unpublished data). The lower detection rate was attributed to a relatively low density of northern goshawks rather than a failure of the broadcast call method to detect northern goshawks. Occupancy checks of historical nest stands in our study were consistent with these regional differences in relative abundance (e.g., east side highest, west side moderate, Olympic range lowest). However, occupancy rates assessed only in historic nest stands may be unreliable indicators of relative abundance and territory occupancy because northern goshawks may nest in uncensused, alternative nest stands within a territory.

In addition to higher rates of occupancy, northern goshawks from east side nest areas might have higher response rates in random surveys because of greater nest success. Ninety-four percent of northern goshawks nesting successfully in both geographic areas responded during the first 4 broadcast trials, with responses occurring at significantly greater rates than on control days. In contrast, 75% of northern goshawks in the small sample of failed nests ($n = 4$) were detected during the nestling period but were unresponsive or absent during postfledging. Similarly, northern goshawks were unresponsive to broadcast calls 1–2 weeks following nest failure in Pennsylvania (Kimmel and Yahner 1990), and northern goshawks were much less likely to be near nests after nest failure in New Mexico and Arizona (Kennedy and Stahlecker 1993). Our overall detection rate of 93% shows that the call technique is especially effective in Washington when conducted within a few hundred meters of occupied nests, although nests that fail have a greater likelihood of going undetected, particularly later in the nest season.

Distance of the surveyor to the nest was expected to affect northern goshawk response as evidenced from previous studies that found the probability of detecting a northern goshawk was highest within 100–200 m of the nest (Kimmel and Yahner 1990, Kennedy and Stahlecker 1993). We found distances of the surveyor to the nest at the point of response to broadcast calls were similar ($\bar{x}$ = 265 m). Our response rates also were greatest at 100 m, moderate at 250 m, and lowest at 400 m. Reduced detection at 400 m could also have been partly a consequence of our limitation to hear responding northern goshawks at this distance, but is probably within the distance of a broadcast call that can be detected by northern goshawks from an 85 dB source (Kennedy and Stahlecker 1993).

For successful nests, the difference in detection rates during broadcasts in the postfledging period (74%) relative to the nestling period (37%) was greater than in other studies for successful nests (i.e., 44% vs. 25% [Kimmel and Yahner 1990]; 77% vs. 73% [Kennedy and Stahlecker 1993]). At randomly surveyed sites, Joy et al. (1994) found greater responses during the nestling period compared to postfledging. In that study, most postfledging responses were by adults (71%), whereas Kennedy and Stahlecker (1993) found the majority (75%) of postfledging responses to be juveniles. In Washington, that juvenile northern goshawks constituted the majority of all respondents (87%) during postfledging is believed to have accounted for the significant differences in detection rates between nest stages. The similarity in postfledging response rates for broadcast and control trials, in contrast to responses during the nestling period, suggests juveniles tended to display greater responsiveness than adults because juveniles responded at similar rates to the presence of the surveyor, whether surveyors called (broadcast trials) or not (control trials). Also, detections were an average of 3 times farther from the surveyor after young fledged. Juvenile northern goshawks also tended to call incessantly after first responding, which accounted for the significantly longer response duration during postfledging and provided a greater likelihood of detection.

MANAGEMENT IMPLICATIONS

The Kennedy and Stahlecker (1993) survey methodology was highly effective for detecting northern goshawks at occupied nests in Washington. Because analysis of detection rates by area did not show an effect of vegetation screening, slope, or topography, differences in the relative abundance of northern goshawks from earlier surveys (WDFW, unpublished data) may reflect true variation in abundance, differences in nest success, or some combination of both.

Our results lend more justification to the use of broadcasts to survey for northern goshawks during the breeding season and provide refinements for improving detection of northern goshawks by broadcast calling in Pacific Northwest forests. Although we did not test the survey methodology from courtship through incubation, we found that call surveys to determine nest-stand occupancy were effective from mid-May, when young hatch on the earliest sites, at least until young were 75 days old in late August. Four days of broadcast calling (adult alarm calls during the nestling period, juvenile food-begging calls during the postfledging period) will result in the detection of most successful nests within the broadcast area. Nests occupied but failed were not likely to be detected by broadcast calling after mid-May. Therefore, if the survey objective is to document nest-stand occupancy over the long term, repeating surveys in >1 year is important. The most efficient use of calling to identify successful nests is to conduct broadcast trials during the postfledging period (i.e., third week of June–first week of July), when response rates are the highest. Because 68% of northern goshawk responses to broadcasts were vocalizations only, surveyors should be aware of the presence of mimics, Stellers jays (*Cyanocitta stelleri*) and gray jays (*Perisoreus canadensis*), which responded to broadcast calls on 10% of all surveys.

In the Pacific Northwest, broadcast calling to detect presence of northern goshawks is typically over vast areas, so maximizing the efficiency of surveys is important and can be achieved by adjusting transect distance and trial frequency. If resources are limited, then reducing the number of trials or increasing the spacing of stations to an acceptable level of detection probability (Fig. 2) is an option. Spacing of stations should range from 200 (i.e., 100-m detection distance) to 800 m (i.e., 400-m detection distance). We found no basis to conclude that detections would be enhanced by stratifying transects by vegetation or topographic interference. Adjacent transects should include offset stations to maximize efficiency (Kennedy and Stahlecker 1993, Joy et al. 1994, Bosakowski and Vaughn 1996).

Variation in northern goshawk detection rates across the species' range, depending on nest period and juvenile presence, may be a result of differences in northern goshawk behavior or habitats among geographic areas. Caution should be taken before using rates of detection from 1 region to determine northern goshawk density or relative abundance in other regions.

ACKNOWLEDGMENTS

Support for this research was provided by the WDFW. The Cle Elum and Randal districts of the U.S. Forest Service, private timber companies including the Boise Cascade Corporation, Port Blakely Tree Farm, and ITT Rayonier allowed access to northern goshawk nests. We thank M. E. McFadzen, M. Suzuki, and C. Fletcher who conducted the majority of field experiments. S. P. Finn and J. Wagenecht provided information on new nest locations and nest status. L. C. Bender, M. L. Nixon, T. Quinn, L. J. Salzer, P. F. Schempf, D. E. Varland, J. M. Williams, and members of the Yakima Management Resource Cooperative provided logistical assistance. We thank P. Garvey-Darda and the Cle Elum Ranger District of the U.S. Forest Service for providing housing to field personnel, and B. J. Behan and D. L. Mueller for cooperation and assistance on surveys in the Randal Ranger District. M. R. Fuller and K. Titus provided excellent comments that improved the manuscript.

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Received 28 July 1997.
Accepted 2 June 1998.
Associate Editor: Diefenbach.