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NORTHERN GOSHAWK BROADCAST SURVEYS: HAWK RESPONSE VARIABLES AND SURVEY COST

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Abstract. We examined responses of Northern Goshawks (*Accipter gentilis*) to taped broadcast calls of conspecifics in tree-harvest areas and around alternate goshawk nests on Kaibab National Forest, Arizona, in 1991 and 1992. Forest areas totaling 476 km^2 were systematically surveyed for goshawks. Ninety responses by adult and juvenile goshawks were elicited and 15 active nests were located. No difference in response rates between sexes was detected. Adult males, however, tended to approach the broadcaster without vocalizing, whereas adult females approached while vocalizing. Our success in finding active nests after getting responses from females was greater than after male responses. Goshawks responded more often to broadcasts during the nestling (2.0 responses/100 stations) than fledgling (1.0 responses/100 stations) period. During the fledgling period, adults were more likely to respond to broadcasts than juveniles. Total costs associated with our surveys for goshawks were $58–82 per km^2 and $4.15–5.80 per broadcast station, depending on salaries.

Key Words: *Accipiter gentilis*; broadcast surveys; Kaibab Plateau; Northern Goshawk; vocalization.

In the southwestern United States, Northern Goshawks (*Accipiter gentilis*) use ponderosa pine (*Pinus ponderosa*), mixed coniferous-deciduous forests, spruce-fir, and pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands. These forests are subject to structural and compositional changes due to plant growth and succession, and to various natural (e.g., fire) and anthropogenic (e.g., tree harvest, grazing) disturbances that may affect goshawk reproductive success (Reynolds 1983, 1989; Crocker-Bedford 1990, Reynolds et al. 1992). In 1982 the Southwestern Region of the USDA Forest Service designated the goshawk as a sensitive species. Reynolds et al. (1992) suggested habitat-management strategies for both goshawks and their prey in ponderosa pine and mixed-species forests. The first step in the management of habitat for goshawks is locating their nests.

Broadcasting of raptor vocalizations has been used to locate goshawk nests (Kimmel and Yahner 1990, Mosher et al. 1990, Kennedy and Stahlecker 1993). Broadcasts elicit vocal and/or visual cues of raptors, which can then be followed with nest searches. During the 1991–1992 breeding seasons we conducted broadcast surveys for goshawks on 12 proposed tree-harvest areas on the North Kaibab Ranger District (NKRD) in northern Arizona.

METHODS

SURVEY AREA

Areas surveyed for goshawks were on the Kaibab Plateau, Coconino County, Arizona. The Plateau is bounded by escarpments and steep slopes that descend into the Grand Canyon of the Colorado River on the south side and desert scrublands elsewhere. Forested areas on the NKRD, which encompasses the northern portion of the Plateau, total approximately 3000 km^2 (Rassmussen 1941). Forests on the Kaibab Plateau consist of a band of pinyon-juniper (1103 km^2) at elevations between 1830–2075 m, ponderosa pine forests (624 km^2) between 2075–2500 m elevation, and mixed-conifer forests (*Abies concolor, Picea engelmannii, Populus tremuloides, Pseudotsuga menziesii*) (605 km^2) above 2500 m (Rasmussen 1941). A complete description of the study area was provided in Reynolds et al. (this volume).

BROADCASTS

We used a modification of the Kennedy and Stahlecker (unpubl. data) broadcast protocol to survey for goshawks. Goshawk vocalizations were broadcast from stations established on parallel transects, and their responses were followed by searches for active nests (containing eggs or young). Responses were classified as (1) vocalization only, (2) sighting only, or (3) vocalization and sighting. We used cassette players (1991 surveys) and portable, long-range callers (1992 surveys) to broadcast goshawk vocalizations. Cassettes were played at a volume that produced a sound audible to the human ear at a minimum of 150 m from the source. Rain, winds exceeding 20 km/h, and occasional vehicle traffic resulted in delay or termination of the survey effort because of the interference with response detection.

Surveys were only conducted during the nestling and fledgling periods when goshawk response rates to broadcasts are highest (Kennedy and Stahlecker 1993). Alarm calls were used during the nestling period and food-begging calls during the fledgling period. For broadcast transects, boundaries of all tree-harvest areas were transcribed onto 7.5-min USGS quadrangle maps. Transects were then drawn with an east-west or north-south orientation depending on topography and accessibility, with both ends of all transects extended 800 m beyond the harvest area boundaries. Distances between transects and stations, as described in Kennedy and Stahlecker (unpubl. data), were modified to increase the theoretical coverage of broadcasts from 78.5 to 90.6% of surveyed areas (Fig. 1). Modifications were that parallel transects were 260 m (vs. 300 m) apart;

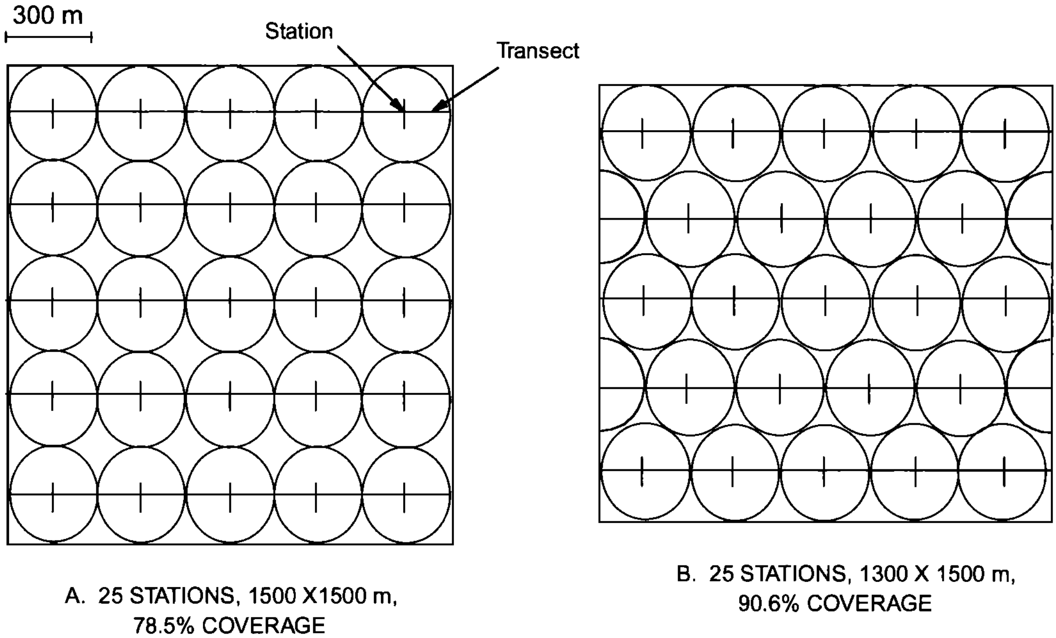

FIGURE 1. Theoretical area of coverage (circles) using (A) Kennedy and Stahlecker's (unpubl. data) transect and station layout, vs. (B) the modified layout used in this study.

and broadcast stations were 300 m (vs. 150 m) apart on each transect and were staggered by 150 m on adjacent transects.

All broadcast stations within 800 m of active nests were deleted from the survey effort. In addition, we did not survey stations in large, treeless openings (diameter > 400 m), on sheer canyon walls, or in stands of Gambel's oak (*Quercus gambelii*), New Mexican locust (*Robinia neomexicana*), or pinyon pine-Rocky Mountain juniper (*J. scopulorum*) that did not contain large ponderosa pine.

Prior to surveys, broadcast personnel were trained in the broadcast technique, field methods, and identification of the calls and physical characteristics of goshawks, Cooper's (*A. cooperii*), Sharp-shinned (*A. striatus*), and Red-tailed (*Buteo jamaicensis*) hawks, and goshawk mimics (e.g., *Cyanocitta* spp.). Observers used the 7.5-min USGS maps with marked transects and stations in the field. At each station, the surveyor broadcasted three times in three directions. First, the surveyor rotated 60° right or left (determined randomly) from the direction of travel, played the taped goshawk vocalization for 10 sec, and then listened and searched in all directions for hawk responses for 30 sec. The broadcast and observation procedures were then repeated two more times after rotating 120° from the previous broadcast. Broadcasts were conducted from 3 June to 12 August between 08:00 and 16:30 MDT.

To avoid misidentifying broadcasts of co-workers, surveyors worked at least two transects apart. When they elicited a response, the following were noted: transect, station, habitat, time, species, sex and age of the hawk, response type, bearing, and estimated initial distance to the responding hawk. All goshawk, and Cooper's, Sharp-shinned, and Red-tailed hawk vocalizations and sightings detected between stations were also recorded. All responses by *Accipiter* spp. were immediately followed with a search for nests within a 200-m radius of the response. Responses by the same species at consecutive stations on a transect were treated as one response.

In 1992, broadcast surveys outside timber harvest areas were conducted within 2 km of three goshawk nests that were active in 1991 but inactive in 1992 to search for alternate nests. An alternate nest is one of several nests used within a goshawk's home range (Reynolds and Wight 1978). In each area, transect and station layout and the protocol described above were used.

Hawk Responses

Chi-square goodness of fit tests (Ott 1984) were used to test the frequency of goshawk responses between sexes, ages (adult, juvenile), nesting stages (nestling, fledgling) (weighted by the number of stations surveyed during stage), and type of vocalizations broadcasted (alarm, food-begging) (weighted by number of stations surveyed with that vocalization) against the null hypothesis of equal frequencies between categories. During 1992 the alarm call was inadvertently used during the first nine days of the fledgling stage. To determine the effect of this, we performed simultaneous tests (Goodman 1964) of response rates to (1) alarm call use (2110 stations) during the nestling stage, (2) alarm call use (1058 stations) during the fledgling stage, and (3) food-begging call use (3681 stations) during the fledgling stage, after standardizing by number of stations surveyed in each category. We also tested whether the success of finding a goshawk nest in follow-up nest searches was independent of the hawk's sex and response type. To examine trends in response parameters, Fisher's Exact test (Proc FREQ; SAS Institute 1987) was used in multi-way comparisons of (1) response type (vocal non-approach, silent approach, vocal approach) by sex, by age, by nesting stage, and by type of broadcast vocalization; and (2) sex of the responder by nesting stage, and by type of vocalization broadcast. We did not test for differences in goshawk response frequency among times of day. Kimmel and Yahner (1990) found that response rates were independent of time of day.

Among-species comparisons of responses of goshawks, and Cooper's, Sharp-shinned, and Red-tailed hawks included the frequency of response type, habitat in which the response occurred, and mean distance from broadcast station to responding individual. In multi-species comparisons, Fisher's Exact Test (Proc FREQ; SAS Institute 1987) was used to test for differences among frequencies of response variables, and the Kruskal-Wallis Test (Proc NPAR1WAY; SAS Institute 1987) was used to test for differences in mean response distances among species.

Survey Effort and Associated Costs

We estimated the effort (surveyor-hours) and costs of using the broadcast survey procedure only during 1992 broadcast surveys. Our estimates included preparing survey maps, training, commuting, conducting surveys, daily data transcription to master 7.5-min maps, testing and maintaining equipment, data entry, checking and analysis, and reporting of results. Expenses are based on salaries, vehicle rents and mileage, and equipment costs and maintenance.

RESULTS

In 1991 we surveyed proposed tree-harvest sites (total area = 183.7 km^2) in the Big Burro, Jack, Jolly, Burnt Saddle-Sowat, Lookout Canyon, Paris, and Stina areas. In 1992 we surveyed proposed tree-harvest sites (total area = 219.5 km^2 + 45.2 km^2 beyond harvest boundaries) in the West Lake, Holy Rock, Road Hollow, Lost Canyon, and Taters areas. A total of 6477 stations were covered requiring 1579 hours of survey time. An additional 27.8 km^2 (391 stations) were covered during surveys for alternate nests.

Hawk Responses

In 1991, 41 goshawk responses were detected during broadcast surveys (2749 broadcast stations, 676 survey-hours) on the seven tree-harvest areas, resulting in 1.5 responses per 100 stations surveyed, 0.2 responses per km^2 surveyed, and 1 response per 16.5 hours of survey time. In 1992 surveys (3728 stations, 903 survey-hours) 48 goshawk responses were detected on five tree-harvest areas, resulting in 1.3 goshawk responses per 100 stations surveyed, 0.2 responses per km^2 surveyed, and 1 response for every 18.8 hours of survey time. One goshawk response was recorded during the 1992 surveys for alternate nests.

TABLE 1. Frequency of Adult Northern Goshawk Responses by Sex to Different Broadcast Vocalizations and during Different Nesting Stages in Broadcast Surveys on the Kaibab Plateau, Arizona, 1991–1992

Variable	Responses: Male	Responses: Female
Vocalization broadcast		
Alarm call	21	15
Food-begging call	6	6
Nesting stage		
Nestling	15	11
Fledgling	12	10

Six and nine active goshawk nests were located during broadcast surveys in 1991 and 1992, respectively. In each year, one of these nests had already been found by a non-broadcast surveyor (Reynolds et al., this volume), but was found again by a naive broadcast surveyor. Thus, one nest was found for every 458 stations covered, 30.6 km^2 surveyed, and 112.7 survey hours in 1991; in 1992, one nest was found for every 414 stations, 29.4 km^2, and 100.3 survey hours. In addition, the number of Cooper's and Sharp-shinned hawk responses during 1991 and 1992 were 14 and 8, and 15 and 6, respectively. Two Cooper's and six Sharp-shinned hawk, and two Cooper's and three Sharp-shinned hawk nests were found during follow-up searches in 1991 and 1992, respectively.

Mean estimated hatching and fledging dates at goshawk nests were 8 June and 17 July in 1991, and 1 June and 5 July in 1992, respectively. In 1991 broadcasting occurred during 18 days (37 surveyor-days) of the nestling period and 31 days (86 surveyor-days) of the fledgling period. In 1992 broadcasting occurred during 19 days (77 surveyor-days) of the nestling period and 26 days (117 surveyor-days) of the fledgling period. Broadcasts of the goshawk alarm call were replaced by broadcasts of the food-begging call on 22 July 1991 and 16 July 1992, coinciding with the latest egg-hatching dates of 24 July 1991 and 15 July 1992.

There was no significant difference in response frequency between adult male and female goshawks ($\chi^2 = 0.75$, df = 1, $P = 0.386$) during 1991 and 1992 broadcast surveys. Furthermore, the frequency of response by sex (in 32 cases the sex could not be determined) was not affected by the type of vocalization broadcasted (N = 48, Fisher's Exact test, $P = 0.741$) or stage of nesting (N = 48, Fisher's Exact test, $P = 1.000$) (Table 1).

TABLE 2. FREQUENCY OF NORTHERN GOSHAWK RESPONSE TYPES BY SEX, AGE, NESTING STAGE, AND BROADCAST TYPE DURING BROADCAST SURVEYS FOR NORTHERN GOSHAWKS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992. N = NUMBER OF STATIONS SURVEYED

	Response type		
Variable	Vocal non-approach	Silent approach	Vocal approach
Sex			
Male	1	17	8
Female	3	3	15
Age			
Adult	4	12	11
Juvenile	9	0	3
Nesting stage			
Nestling (N = 2129)	9	15	17
Fledgling (N = 4739)	18	13	14
Vocalization broadcasted			
Alarm call (N = 3168)	12	23	23
Food-begging call (N = 3700)	15	5	8

Response type, however, differed between the sexes (N = 47, Fisher's Exact test, P = 0.001) (Table 2); males often approached silently, whereas females most often approached and vocalized. More active nests were found in follow-up searches to responses by females (N = 8 nests of 21 responses) than males (N = 3 nests of 27 responses) (N = 48, Fisher's Exact test, P = 0.040).

During the fledgling stage, adults responded to broadcasts more often than juvenile hawks (χ^2 = 7.05, df = 1, P = 0.008; N = 29 and 12 responses, respectively). Also, adults were more likely to approach the broadcaster (either vocalizing or silent) than juveniles (N = 93, Fisher's Exact test, P < 0.001) (Table 2).

During both years, more stations were surveyed during the fledgling (4739 stations) than the nestling (2129 stations) stage. After adjusting for these differences, goshawks responded more often during the nestling stage (42 responses per 2129 stations) than the fledgling stage (48 responses per 4739 stations) (χ^2 = 10.33, df = 1, P = 0.001), whereas response type was independent of nesting stage (N = 86, Fisher's Exact test, P = 0.202) (Table 2).

The number of stations surveyed with the alarm and food-begging calls also varied (alarm call = 3168 stations, food-begging call = 3700 stations). After adjustment, goshawks responded more often to the alarm (N = 59 responses/effort) than food-begging (N = 31 responses/effort) call (χ^2 = 13.69, df = 1, P < 0.001). Response type (4 of 90 responses were unclassified) was not independent of the type of call broadcasted (N = 86, Fisher's Exact test, P = 0.008) (Table 2). Alarm calls more commonly elicited a silent approach or vocal approach, whereas food-begging calls more often elicited vocalization with no approach. More nests were found during follow-up searches to vocal approaches (N = 31 nests) than to vocal non-approaches (N = 27 nests) or silent approaches (N = 28 nests) alone (N = 86, Fisher's Exact test, P = 0.029).

The overall chi-square among the three categories of call-use by nesting stage (alarm call during the nestling stage, alarm call during the fledgling stage, and food-begging call during the fledgling stage) was significant (χ^2 = 14.90, df = 2, P = 0.013). Response rates were significantly higher using the alarm call during the nestling stage than using the food-begging call during the fledgling stage. However, goshawk response rates using the alarm call during the fledgling period were not significantly different from using the food-begging call during the fledgling period, nor did the former differ from using the alarm call during the nestling period.

Overall, the frequency of response types among the three species of *Accipiter* did not differ (N = 123, Fisher's Exact test, P = 0.208), nor did they differ between any *Accipiter* and Red-tailed Hawks (Fisher's Exact test, P > 0.016, Bonferroni significance level, for all pairwise tests). However, when responses were partitioned by habitat (ponderosa pine, mixed-conifer forests), the frequency of responses among all species differed (N = 210, Fisher's Exact test, P = 0.014) (Table 3). Goshawk and Cooper's and Red-tailed hawks responded more often in ponderosa pine forest, whereas Sharp-shinned Hawks responded more often in mixed-conifer forests. Mean response distance was not equal among species (P

TABLE 3. FREQUENCY OF NORTHERN GOSHAWK, COOPER'S HAWK, SHARP-SHINNED HAWK, AND RED-TAILED HAWK RESPONSES BY HABITAT DURING BROADCAST SURVEYS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992

Habitat	Species			
	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk	Red-tailed Hawk
Ponderosa pine	50	17	5	62
Mixed-conifer	38	7	9	22

< 0.001); Red-tailed Hawks responded at distances greater than any of the *Accipiter* ($P < 0.016$, Bonferroni significance level, in all pairwise tests) (Table 4). Response distances did not differ among the *Accipiter* species ($P = 0.492$).

SURVEY EFFORTS AND ASSOCIATED COSTS

In 194 surveyor-days during 1992, observers surveyed 3728 stations (265 km^2 of transects) for a mean survey effort of 19.3 (SD = 6.8) stations per day. Of the 4832 established stations (343 km^2), 1104 stations (78.4 km^2) were not surveyed because they occurred in non-forested habitat or were within 800 m of an active goshawk nest.

Eleven observers spent 0.5–10.0 h ($\bar{X} = 4.7$ h, SD = 1.7) per day surveying for a total survey time of 903.1 h. Mean time required to broadcast, observe, and travel to the next station was 14.5 min per station. A mean of 8.4 h per day (SD = 1.7, total time = 1627 h) per observer was required to broadcast, commute to and from survey sites, update master survey maps, and test and maintain equipment. An additional 184 surveyor-hours were required for training personnel and 252 h were required on pre- and post-season tasks such as preparing survey maps, selecting personnel, data entry and verification, analysis, and report writing. Total personnel costs to complete broadcast surveys of the five tree-harvest areas surveyed in 1992 ranged from $4.15–5.80 per station and $58.50–81.85 per km^2 ($151.40–211.95/mi^2) depending on salary (Appendix). Vehicle and equipment costs were $1.90 per station and $26.70 per km^2 ($69.30/mi^2) surveyed.

DISCUSSION

HAWK RESPONSES

Response rates of goshawks to broadcasts did not differ between the sexes, but male and female behaviors differed when responding. As measured by their intensity of vocalization, females responded more aggressively than males. Males appeared to be more inquisitive than aggressive in their initial response, often approaching and retreating silently. The probability of finding a nest during follow-up searches to female responses was greater than for male responses. Females are more likely to be in the vicinity of their nests during early stages of brood-rearing whereas males are more likely to be away from nests foraging. However, because of potential bias in the misidentification of sex, and because males will respond from their nests, we recommend that equal effort be given to follow-up searches to responses by either sex.

Contrary to Kimmel and Yahner's (1990) report that no difference occurred in response rates between nesting stages, we found that goshawk responses rates were higher during the nestling than fledgling stage. No difference in response rates to the alarm and food-begging calls during the fledgling stage was detected during our surveys. Kennedy and Stahlecker (1993), however, detected fewer responses using the alarm call vs. the food-begging call during this period.

During the fledgling stage, adult response type (silent and vocal approaches to the observer) differed from juvenile response type (vocal non-approaches). This difference may reflect the inability of fledglings to fly well and a reluctance to leave the nest area. Juveniles vocally responded with both alarm and food-begging calls.

Response type to the calls broadcasted (alarm, food-begging), when both nesting stages were combined, differed. More approaches, with and without vocalization, were tallied in response to the alarm call whereas more vocalizations without approach were tallied to the food-begging

TABLE 4. MEAN INITIAL-RESPONSES DISTANCE, STANDARD DEVIATION, AND NUMBERS OF NORTHERN GOSHAWK, COOPER'S HAWK, SHARP-SHINNED HAWK, AND RED-TAILED HAWK RESPONSES TO BROADCAST SURVEYS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992

Variable	Species			
	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk	Red-tailed Hawk
Mean response distance (m)	95.4	75.8	77.0	148.1
SD	87.5	71.1	73.5	121.3
No. of observations	90	26	14	89

call. This pattern reflects the tendency of adults to respond to the alarm call and juveniles to the food-begging call. A high number of vocal responses without approach were also tallied by Kennedy and Stahlecker (1993) during the fledgling stage.

Forests surveyed during 1991 and 1992 were primarily ponderosa pine and mixed-conifer. A greater proportion of goshawk, and Cooper's and Red-tailed hawk responses to goshawks vocalizations were obtained in ponderosa pine than in mixed-conifer forests. For Sharp-shinned Hawks, a greater proportion of responses were obtained in mixed-conifer forest. Mixed-conifer forests are often more structurally and floristically diverse than ponderosa pine forests and probably provide greater hiding cover for Sharp-shinned Hawk nests and higher densities of their prey. Initial response distance to broadcasts was greater for Red-tailed Hawks than any of the *Accipiter* spp. Red-tailed Hawks soar more often than the *Accipiter* and are easier to detect at greater distances.

We think that the Kennedy and Stahlecker (1993) protocol (with modifications described herein) is an effective means of locating goshawk, and Cooper's and Sharp-shinned hawk nests. Blind tests of the efficacy of the broadcast-survey method need to be conducted to determine the proportion of nests missed and the number of survey visits required to achieve an acceptable level of detection. Until such tests are performed, guidelines for surveying proposed tree-harvest areas should require two or more visits in separate years to increase the probability of goshawk detection. Tests of the efficacy of using goshawk vocalizations versus those of congeners to find Cooper's, Sharp-shinned, and Red-tailed hawk nests should be pursued.

Survey Effort and Associated Costs

Estimates of cost/effort of locating goshawk nests using methods similar to Kennedy and Stahlecker (1993) were not available for comparison with our estimates. Costs associated with surveying for goshawks (personnel, vehicle, and equipment) vary depending on survey effort and size of the survey area. If finding all goshawk nests is the objective of surveys, effort should not be compromised in order to cover larger areas.

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APPENDIX. PERSONNEL COSTS FOR CONDUCTING NORTHERN GOSHAWK BROADCAST SURVEYS PER BROADCAST STATION AND AREA, ON THE KAIBAB PLATEAU, ARIZONA, IN 1992

Variable	Personnel salary level $7.50/hour	$8.50/hour	$10.50/hour
Survey time only			
Per station[1]	$ 1.80	$ 2.05	$ 2.54
Per km^2 [2]	$ 25.60	$ 29.00	$ 35.80
Per mile^2 [3]	$ 66.30	$ 75.10	$ 92.80
All survey-related tasks[4]			
Per station	$ 4.15	$ 4.70	$ 5.80
Per km^2	$ 58.50	$ 66.25	$ 81.85
Per mile^2	$151.40	$171.60	$211.95

[1] Costs determined over 3728 stations that required 903 surveyor-hours of broadcasting.
[2] Costs determined over 264.7 km^2 that required 903 surveyor-hours of broadcasting.
[3] Costs determined over 102.2 mi^2 that required 903 surveyor-hours of broadcasting.
[4] Costs determined over 2063 h required to survey 3728 stations (or 264.7 km^2, or 102.2 mi^2), prepare survey maps, train, travel daily to and from survey sites, conduct surveys, update of "master" survey maps (area covered daily), test and maintain equipment, enter, error-check and analyze data, and report results.