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SURVEYING WOODLAND RAPTORS BY BROADCAST OF CONSPECIFIC VOCALIZATIONS

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Abstract.—We surveyed for raptors in forests on study areas in five of the eastern United States. For Cooper's Hawks (*Accipiter cooperi*), Red-shouldered Hawks (*Buteo lineatus*), and Barred Owls (*Strix varia*) the contact rates obtained by broadcasting taped vocalizations of conspecifics along roads were significantly greater than contact rates obtained by only looking and listening from the roadside. Broad-winged Hawks (*B. platypterus*) were detected only after their calls were broadcast. Most raptors were detected within 10 min of the beginning of the broadcasts. Red-tailed Hawks (*B. jamaicensis*) and Goshawks (*A. gentilis*) nested infrequently on our study areas, and we were unable to increase detections of these species. Generally, point count transects along woodland roads, from which conspecific vocalizations were broadcast, resulted in higher species specific detection rates than when walking, driving continuously, or only looking and listening for raptors at roadside stops.

CONTEO DE AVES RAPACES EN ÁREAS BOSCOSAS UTILIZANDO GRABACIONES DE LA VOCALIZACIÓN DE CONESPECÍFICOS

Sinopsis.—Llevamos a cabo un conteo de aves rapaces en bosques del este de los Estados Unidos. El número de contactos visuales o auditivos obtenidos mediante el uso de grabaciones de la vocalización de conespecíficos de *Buteo lineatus, Accipiter cooperi,* y *Strix varia* fue significativamente mayor a lo largo de caminos, que los contactos obtenidos cuando tan solo se trató de escuchar u observar a las aves en las mismas localidades. *Buteo platypterus* tan solo fue localizado mediante el uso de grabaciones. La mayoría de las aves estudiadas fueron localizadas en el lapso de los 10 minutos luego de haber sido utilizada la grabación de su vocalización. Las únicas dos especies que no fueron localizadas con mayor frecuencia resultaron ser *B. jamaicensis* y *A. gentilis,* aunque éstas anidan con poca frecuencia en las áreas estudiadas. En general, la utilización de transectos con puntos a lo largo de caminos, en donde se utilizó la vocalización de rapaces, resultó en un incremento en la detección de éstas, en contraste a la utilización de métodos más convencionales como caminar, conducir un vehículo o tan solo observar o tratar de escuchar rapaces en puntos localizados a lo largo de caminos.

Raptor surveys are often time-consuming compared to surveys of more abundant species (Fuller and Mosher 1981). Therefore, we broadcast

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recorded vocalizations of several species of raptors to: (1) determine if broadcasting of conspecific vocalizations increases detectability, (2) measure latency of contacts following initiation of broadcast, and (3) measure variations in detectability throughout the breeding season. This approach has been applied to many avian taxa (Johnson et al. 1981, Marion et al. 1981), including North American owls (e.g., Forsman et al. 1977, Foster 1965, Gould 1979, McGarigal and Fraser 1985, Springer 1978). Broadcast of vocalizations has been used also to locate nests of some diurnal raptors (Hennessey 1978, Rosenfield et al. 1985, M. Root and P. Disimone, pers. comm.). However, the effectiveness of broadcast vocalizations to increase raptor detections has been documented only for Cooper's Hawks (*Accipiter cooperi,* Rosenfield et al. 1988).

Other raptor counts, for example a BBS route, usually do not provide enough contacts to be useful. We compare our broadcast results to two other common methods—walk for nests, continuous road count of all species—and conclude that broadcast calls produce the most contacts per unit effort (time).

METHODS

We established one transect of unlimited width along a secondary road through a forested area of apparently suitable nesting habitat in study areas in Connecticut (2), Maryland (2), New Hampshire (1), New York (1), and Wisconsin (1). We designated one to five target species for each transect, each year. Transects were 7.2 km (4.5 mi) long, comprising ten stops at 0.8 km (0.5 mi) intervals. Each study area extended to a radius of 1.6 km (1.0 mi) beyond the first and last stops and 1.6 km (1.0 mi) to each side of the transect, encompassing about 31.1 km^2 (12.1 mi^2). We repeated point count transects (Ralph and Scott 1981) for each species at approximately 8-d intervals from about mid-March to mid-July. We define a "count" as the process of enumerating the contacts (visual or auditory detections) at the 10 stops along each transect. Counts were not made in fog, steady drizzle, prolonged rain, or winds greater than Beaufort 3 (13–19 km/h). The ambient temperature was measured and wind was estimated at the beginning and end of the transect.

During 1980 and 1981 the observer remained at each stop 20 min to record data in four periods: a 5-min period prior to broadcasting (PRE), a 5-min broadcasting period (BRD), a 5-min period immediately following the final broadcast vocalization (PST5), and 5–10 min after broadcast (PST10). In 1982 the PRE and PST10 periods were eliminated because few birds were detected during these times and field time was better spent on other activities. At each stop the start and end times of each period were recorded. The following information was recorded for each raptor contact: species; contact type, auditory, visual, or both; latency, in minutes, from the first broadcast vocalization until the initial contact.

During 1980, vocalizations (five 15-s calls, evenly spaced over 5 min) of one target species were broadcast toward only one side (selected by coin toss) of the transect at each stop. Beginning in 1981 the 5-min broadcast period consisted of six 15-s vocalizations distributed evenly over

5 min. The speaker was rotated 180° after each vocalization, resulting in three sets of calls broadcast toward each side of the transect at each stop. This change was made to save time and further standardize the procedure. We have no evidence that the modifications affected survey results.

Raptor vocalizations used in this study were recorded onto cassette tapes from record albums (Peterson Field Guide Series, A Field Guide to Bird Songs of Eastern and Central North America) (Broad-winged Hawk *Buteo platypterus* and Goshawk *Accipiter gentilis*); and National Geographic Society, Bird Sounds of Marsh, Upland, and Shore (Red-tailed *B. jamaicensis,* Red-shouldered *B. lineatus* and Cooper's hawks *A. cooperi* and Barred Owl *Strix varia*). We used Marantz model C-205 cassette decks powered by disposable batteries, rechargeable Ni-Cad batteries, or a vehicle's 12-volt battery through a cigarette lighter adapter (use of product names does not imply endorsement by the U.S. Government). Vocalizations were broadcast through an 8-ohm trumpet speaker (model HFA-12, Fanon/Courier Corporation) placed on the roof of a vehicle about 2 m above ground.

We measured attenuation of broadcast vocalization using a General Radio Corporation model 1933 Sound Analysis System in a sample of woodland habitat in Maryland. This area consisted of a uniform stand of White Oak-Maple woods with moderate to low ground cover and little understory vegetation. We measured sound intensity (dB) at seven distances from the source (2.5, 5.0, 10.0, 25.0, 75.0, and 100.0 m) and seven deviations from the directional axis of the speaker (0, 30, 45, 60, 90, 135, and 180 degrees) at each distance. We walked a transect away from the speaker to determine the distance at which we could no longer hear the broadcast. We broadcast vocalizations from 2.0 m, above ground level and held the sound level meter at about 1.0 m. Nine dB measurements were taken at each distance/deviation position. Regression analyses were performed with y = dependent variable = dB level, and x = independent variable = distance from source.

Contact rates were calculated for driving (excluding point count transects), conducting point count transects, and systematic nest search (walking). Calculations for the latter excluded time spent walking to known active nest sites, and data from study areas where prior experience might have biased searches. Study areas were systematically searched on foot for raptor nests three times during the breeding season. Biologists would walk parallel lines through the area noting any nest structures or sign indicative of raptor activity. Areas of potential activity were revisited throughout the breeding season to confirm nesting. Analysis of variance was used to test for differences in rates of detection between the three types of field activities.

The number of contacts with each species on each point transect was tallied from all study areas and years for each broadcast period. We used sign tests to test the equal likelihood of contacting a raptor in each 5 min time period (before broadcast, during broadcast, the first 5 min after broadcast, and the last 5 min). We used a Chi-square test to determine the latency among the three periods (during broadcast and each 5 min period after broadcast), and if there were differences among contact rates during three stages of the breeding season.

RESULTS

Acoustics.—Sound level declined exponentially with distance from the speaker for all directional deviations from the axis of the speaker. There was no significant difference among the regression equations for vocalizations of the different species. Therefore, all data were combined, with the resulting regression equation being: $dB = 94.1 - 22.4(\log_{10} \text{distance})$; $F = 206$; df = 1,19; $r^2 = 0.92$, for those measurements taken at 0° deviation from the speaker. The equipment used produced sound levels between 100 dB and 110 dB at 1 m in front of the speaker. Background noise was usually between 30 and 40 dB, and the broadcast sound level was predicted to drop to this level about 750 m from the speaker. We could still discriminate the broadcast from the background noise at 750 m.

Contact rates during point transects.—The contact rates with several hawk species and Barred Owls were variable among study areas and years (Table 1). No contacts were made during years when no active nests were found on the study areas. In some years, no contacts were made with Cooper's Hawks or Broad-winged Hawks when they nested. The average number of detections per count, based on all years and on all study areas was: 1.21 for Red-shouldered Hawks, 0.29 for Cooper's Hawks, 0.77 for Broad-winged Hawks, and 13.3 for Barred Owls. Red-tailed Hawk and Goshawk contacts were too few to permit detailed analysis. No contacts were made with Goshawks on the New York study area even though one pair nested just outside the study area across a lake from the survey route. In Connecticut, Goshawks nested on the study area, but only five contacts were made during point transect counts.

A comparison of contact rates by period showed that Red-shouldered Hawks and Cooper's Hawks were contacted more frequently ($P < 0.05$) during or after broadcast than when the observer was merely listening and watching (Table 2). Broad-winged Hawks were contacted on point counts only during or after broadcasts of their vocalizations. Barred Owls were contacted less frequently during broadcasts than before the tape was played. However, more contacts occurred following the broadcast than before the tape was played ($P < 0.01$).

Latency.—More initial contacts with Red-shouldered and Broad-winged hawks occurred during either broadcast or in the first 5 min after, than in the 5–10 min period following broadcsast, and contacts with all hawks combined occurred significantly more ($P < 0.01$) during the broadcast or 5 min post-broadcast periods than the 5–10 min post-broadcast period (Table 3).

Contact rates during breeding stages.—We separated contacts among the pre-incubation, incubation, and post-incubation stages of the breeding cycle. This is difficult because on any study area three different pairs of the same species might be in three different stages. Data for this analysis were gathered only from the Maryland study areas where reproductive

TABLE 1. Contact rates (number of contacts per 10-station count) from point transect counts for raptor species when broadcasting conspecific vocalizations.[1]

State and year	Red-shouldered Hawk	Broad-winged Hawk	Cooper's Hawk	Barred Owl
New York				
1981	0.00 (2)[2]	0.00 (8)	0.00 (1)	17.00 (2)
1982		1.67 (6)	0.00 (2)	
Mean[3]		0.84 ± 0.84	0.00	
New Hampshire				
1980		0.64 (11)		2.09 (11)
Connecticut				
1981	0.91 (11)			
Wisconsin				
1980			0.50 (6)	8.78 (9)
1981	0.55 (11)		0.00 (10)	14.10 (10)
1982	0.18 (11)		0.00 (11)	
Mean	0.41 ± 0.20		0.17 ± 0.17	11.44 ± 2.66
Maryland				
1980	1.23 (13)		1.10(10)	15.00 (13)
1981	1.94 (16)		0.44 (9)	23.09 (11)
1982	3.67 (3)			
Mean	2.28 ± 0.72		0.77 ± 0.33	19.05 ± 4.05
Combined mean	1.21 ± 0.48	0.77 ± 0.49	0.29 ± 0.16	13.34 ± 2.94

[1] Includes contacts during the broadcast and 0–5 min postbroadcast period.
[2] Number of routes (n).
[3] Mean ± standard error.

chronology was followed (e.g., Janik and Mosher 1982). There were no differences in contacts ($P < 0.05$, Chi-square) among the breeding stages for Cooper's or Red-shouldered hawks (Table 4).

Walking and driving.—A summary of the field workers documentation of time spent in each type of survey and the number of raptor detections

TABLE 2. Contacts per hour with raptors during the periods spent at each station along a point count transect.

	Station period			
	Pre-broadcast	Broadcast	0–5 min Post-broadcast	6–10 min Post-broadcast
Broad-winged Hawk	0.0 ± 0.0	0.3 ± 0.3	0.5 ± 0.4	0.3 ± 0.3
Red-shouldered Hawk	0.3 ± 0.3	0.6 ± 0.2*	0.4 ± 0.3*	0.3 ± 0.2
Cooper's Hawk	0.03 ± 0.0	0.1 ± 0.2	0.2 ± 0.2*	0.2 ± 0.2
Barred Owl	4.0 ± 0.8	2.5 ± 0.5	6.6 ± 0.7*	4.9 ± 0.7

* Significantly ($P < 0.05$) greater likelihood of contacts compared to Pre-broadcast period (Sign test).

TABLE 3. Latency of contacts with raptor species by station period.[1]

	Broadcast	0–5 min Post-broadcast	6–10 min Post-broadcast
Cooper's Hawk	5 (33)[2]	5 (33)	5 (33)
Northern Goshawk	2 (40)	1 (20)	2 (40)
Red-shouldered Hawk*	42 (56)	26 (35)	7 (9)
Broad-winged Hawk*	7 (54)	6 (46)	0 (0)
All hawks combined*	56 (52)	38 (35)	14 (13)
Barred Owl*	105 (19)	313 (57)	128 (23)

[1] Sample sizes differ from Table 2 because analyses were based on different sets of study area and/or year.
[2] Number of contacts (%).
* Contacts not distributed equally among periods χ^2 ($P < 0.05$).

in each survey type included 0.21 target species/h while systematically walking in search of nests; 0.55 hawks of all species/h while driving; and 0.49 target species/h from the point count transects during broadcast and the first 5 min post-broadcast. Fewer raptors were detected while walking, and there was no significant difference among the contact rates of all species while driving and only target species when using broadcasts.

DISCUSSION

The comparison of contact rates obtained before and after broadcasting conspecific vocalizations suggests several woodland raptors can be detected more frequently by broadcasting calls. We recognize that many factors can affect raptor survey results and compromise their usefulness and comparisons among them (Fuller and Mosher 1981, 1987). When conducting avian surveys one can expect differences among observers, re-

TABLE 4. Red-shouldered Hawk and Cooper's Hawk contacts per point transect during three stages of breeding cycle in Maryland.[1]

Year	Breeding stage: Pre-incubation	Incubation	Post-incubation
Cooper's hawks			
1980	10/3	3/5	1/2
1981	0/3	3/4	1/1
1982	9/4	6/2	1/1
Combined	19/10 (1.9)	12/11 (1.1)	3/4 (0.8)
Red-shouldered hawks			
1980	6/3	1/3	6/7
1981	5/5	8/4	10/7
1982	0/0	8/2	3/1
1983	0/0	6/4	3/6
Combined	11/8 (1.4)	23/13 (1.8)	22/2 (1.0)

[1] Number of contacts/number of 10-station routes run.

sponsiveness of individual birds and species, and differences in detectability as a function of species, terrain and vegetation structure (Ralph and Scott 1981). We suspect that the variability in contact rates among our study areas and years was due, in part, to differences in topography, vegetative structure, and raptor density. However, our trials were conducted in nesting habitat that is generally similar in much of the northeastern quarter of the United States (Devereux and Mosher 1984, Mosher et al. 1986). Therefore, our contact rates should be representative for the Red-shouldered, Broad-winged, and Cooper's hawks and Barred Owls. Furthermore, the use of broadcast procedures and equipment similar to those we used will contribute to standardization.

Our equipment produced broadcast vocalizations that performed as expected based on the physics of sound in vegetation (Aylor 1972). We broadcast raptor vocalizations of 1.5 to 4.0 kHz (Robbins et al. 1966). These frequencies are within the mid-range values least likely to be affected by vegetation (Richards 1981) and were broadcast far enough from the ground (1.5–2.0 m) to avoid excessive attenuation that occurs at the surface (Marten and Marler 1977). We avoided additional attenuation by not broadcasting during strong or gusty winds or beyond mid-morning when temperatures and increased background noise affect sound propagation (Wiley and Richards 1978, 1982).

Sound levels were audible to the human ear at least to 750 m, at which distance the broadcast sound level approached that of background levels. Dooling (1982) noted that Budgerigars (*Melopsittacus undulatus*) can better detect sounds in noise than humans. It is unknown to what degree the target species can "filter" vocalizations from background noise. However, we assume that most raptors within our 31.1 km^2 study area could hear broadcasts from at least one of the stops on the transect.

We found no differences in detection rates among the pre-incubation, incubation, and post-incubation stages of Cooper's and Red-shouldered hawks. Because there often are differences in the breeding chronology among raptors in an area and because rates of detection are low, we cannot specify a phase of the cycle within which one could restrict counts. The lack of difference in contact rates during the breeding season suggests birds did not stop responding due to habituation to broadcasts. However, habituation has been suspected (Johnson et al. 1981, Smith 1981), thus there might be limits to how often vocalizations should be broadcast. We suggest beginning surveys 1–2 wk prior to egg laying to reduce contacts with migrants, and broadcasting about once per week. We never contacted a target species that was not found nesting on the study area, and only on a few occasions were birds in sub-adult plumage observed at broadcast stops. Thus we believe that the technique is selective for territorial adults.

Most detections occurred during broadcasts and the following 5 min. Ninety-one percent of the Broad-winged and Red-shouldered hawk contacts occurred in that 10 min period. More Barred Owls were heard after vocalizations had been broadcast. For intensive surveys of relatively small areas (e.g., <15 km^2), one might remain at a stop 15 min. However, for larger areas we suggest 10 min per stop, then allocating the extra time to additional stops and transects.

Broadcasting the tape-recorded vocalizations along roadways was associated with our only detections of Broad-winged hawks, and provided a significantly greater number of contacts with Red-shouldered and Cooper's hawks and Barred Owls than when we simply stopped, looked and listened for birds. Our results support the belief that broadcasting raptor calls increases contact rates (e.g., Balding and Dibble 1984, Forsman et al. 1977). Geissler and Fuller (1986) use broadcast and repeated counts to estimate the probability of detection and proportion of area occupied, which allow statisical comparisons of survey results from different areas and periods. The point count transects with broadcasts provided a greater contact rate than walking to look for raptors and their nests. Rosenfield et al. (1985, 1988) have used broadcasts to find Cooper's Hawk nests. We could not directly compare our continuous driving and point count transects, but we did not find any difference between the rate at which all hawk species were detected while driving and the contact rate for target species only when we used broadcasts on point transects. Consequently, we recommend broadcasts on point transects to increase raptor contacts, and we encourage additional research into the relationship of broadcasts, raptor detection rates, and raptor abundance.

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