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FACTORS AFFECTING DETECTION OF GREAT HORNED OWLS BY USING BROADCAST VOCALIZATIONS

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Populations of great horned owls (*Bubo virginianus*) have increased in southern Pennsylvania since the early 1970's, based on recent evidence from Christmas Bird Counts (CBC) (Goodrich and Senner 1989). However, to determine the long-term status of populations of great horned owls and to enable state and federal agencies to address questions dealing with relationships between owl abundance and changing land uses or prey abundance, a standardized survey technique needs to be developed that is both cost- and labor-efficient. Although broadcasts of conspecific recordings have been used to determine the presence of owls, including great horned owls (e.g., Springer 1978, Lynch and Smith 1984, McGarigal and Fraser 1984, Brenner and Karwoski 1985), none has been rigorously field-tested. Further, factors that may influence responses of owls to taped playbacks, such as weather conditions,

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must be considered when conducting surveys (Fuller and Mosher 1987). Survey techniques (e.g., direct counts, nest searches) that are used to monitor other bird species usually are not practical for great horned owls because individuals are nocturnal, secretive, and mobile and because nests are widely dispersed. Thus, our objectives were to (1) determine the influence of temporal, weather, and lunar factors on vocalizations of great horned owls, and (2) develop a standardized survey technique for indexing numbers of great horned owls.

STUDY AREA

We conducted our study in 15 counties of south-central Pennsylvania. The study area included 3 physiographic regions (Ridge and Valley, Blue Ridge, and Piedmont) that ranged from 21 m to 956 m in elevation. The Ridge and Valley Region is characterized by forested ridges that are long, narrow, parallel, and even-crested. Lower elevations between ridges in this region are typically broad and relatively level farmlands (Gifford and Whitebread 1951). Most ridges contain second-growth forests, with old-growth remnants occurring in a few places (Braun 1950). Forests are predominantly northern red (*Quercus rubra*), white (*Q. alba*), chestnut (*Q. prinus*), and scarlet (*Q. coccinea*) oaks (Braun 1950). Northern hardwoods occur as isolated pockets along higher ridges, consisting of beech (*Fagus* spp.), birch (*Betula* spp.), maple (*Acer* spp.), and eastern hemlock (*Tsuga canadensis*) (Braun 1950). In the Blue Ridge and Piedmont Regions, red, white, chestnut, and scarlet oaks predominate, with post oak (*Q. stellata*) and blackjack oak (*Q. marilandica*) also being common in the Piedmont Region (Braun 1950).

Mean daily minimum temperature in the study area ranged from −12.0 to 10.2 C between January and May. Mean daily maximum temperature ranged from 2.7 to 23.4 C, and mean monthly precipitation was 41.1 cm from January to May.

METHODS

We conducted surveys of owl numbers along 56 16-km survey routes. To select routes, 30 of 126 topographic maps (1:24,000) covering the study area were randomly selected. Two 16-km routes then were established on each map by randomly choosing a light-duty road from the map. Direction of travel along a route was selected randomly if the entire length of the route remained on the map. If a route occurred within 1.6 km of another route or if it meandered excessively, it was modified or excluded to avoid covering an area more than once.

Ten stations were established at 1.6-km intervals along each 16-km survey route. Owls were surveyed at each station by broadcasting a tape recording of the call of a "hooting" great horned owl (hereafter referred to as a broadcast) obtained from the Cornell Library of Natural Sounds, using a speaker-amplifier system. The system consisted of a Perma-Power Half-Miler Hailer (Model S-610, Perma-Power Electronics, Inc., Chicago, Ill.) and a portable cassette player. At each station, an observer exited the vehicle and listened for unsolicited owl calls (a "hooting" owl) for 2 minutes. The broadcast then was played for a 5-minute period during which all responding owls were recorded. A broadcast consisted of 6 sets of a 20-second owl call, with each set separated by 40-second pause intervals. Each set consisted of a series of 4 4–7 note songs. The first 20-second broadcast was made holding the speaker perpendicular to the direction of the road, with the speaker rotated 180° following each 20-second broadcast. Immediately after the final 20-second broadcast, 5 minutes was spent at the station to record responses of owls. Audio output of the playback was adjusted periodically to maintain 90–110 decibels (Fuller and Mosher 1987) as recorded by a hand-held sound meter.

All surveys were conducted between 1600 and 0800 hours. Surveys were not conducted when wind velocity consistently exceeded 12 km/hour or when precipitation was steady. During each visit to a station, we recorded the visit number (number of times the route had been surveyed, including the present survey), and 2 temporal, 4 weather, and a lunar variable. The 2 temporal variables were monthly time period and daily time period. Monthly time period was divided into 4 periods (Jan, Feb, Mar, and Apr–May), and daily time period was separated into 6 periods (1600–1959, 2000–2159, 2200–2359, 0000–0159, 0200–0359, and 0400–0800 hr). Four weather variables were temperature, wind velocity, cloud cover, and precipitation. Temperature was divided into 6 categories (≤ -11, -10 to -6, -5 to 0, 0 to 5, 6 to 10, and ≥ 11 C). Wind velocity was measured once at a station and classified into 3 categories of the Beaufort scale (0, 1, and 2). Cloud cover consisted of 4 categories (0–25, 26–50, 51–75, and 76–100%). Two categories of noticeable precipitation (present or absent) were used, and 4 categories of lunar periods were designated (day following a new moon to and including a first quarter moon, day following a first quarter moon to and including a full moon, day following a full moon to and including a last quarter moon, and day following a last quarter moon to and including a new moon).

When an owl was first seen or heard (contact), we noted the broadcast period (pre-, during, and post-), time to respond to the broadcast (min from start of broadcast, not including those contacts made during the prebroadcast), sex, and response type. Sex class was determined by the tone of call, with males having a lower, deeper call than females (Miller 1930). Response type consisted of 6 categories: spontaneous vocalization (vocalized during the prebroadcast period), approached but did not vocalize, vocalized before approaching, approached then vocalized, vocalized but did not approach, and owl flushed from the area. An owl was determined to be approaching if observed flying towards the station or heard alighting on nearby branches.

Each route was surveyed 3–7 times during 1 year from January to May, 1987 or 1988. Due to snow accumulation, some routes often were impassable; thus, we were unable to visit all routes an equal number of times. A minimum of 4 days elapsed between visits to the same survey route. We began our surveys in January to correspond to the timing of territorial defense, and continued until late May, which coincides with fledging of owlets that still depend on parents for food (Bent 1938, Austing and Holt 1966). Routes were not surveyed in November or December because we wanted to ensure that territorial defense was in progress.

Dependency of frequencies of owl contacts on weather, temporal, and lunar variables was analyzed separately using *G*-tests for goodness-of-fit (Sokal and Rohlf 1981:705). For each weather, temporal, and lunar variable, we tested the hypothesis that the observed ratio of owl contacts during each category was equal to an expected ratio. The expected ratio was based on the proportion of total survey effort for a given variable category (e.g., category Jan for variable monthly time periods) multiplied by the total number of owl contacts recorded; survey effort was the total number of visits to individual survey stations for that variable category. *G*-tests also were used to test the hypothesis that observed and expected ratios of owl contacts did not differ between years and between sex class for each temporal, weather, and lunar variable when sample sizes were adequate. In addition, *G*-tests were used to test the hypothesis that the ratio of observed and expected owl contacts did not differ among the 6 responses and also were used to determine if there was a relationship between response type and temporal, weather, and lunar variables when sample sizes were adequate.

Log-linear analysis (BMDP4F, Dixon 1985:143) was used initially to explore relationships among variables. All possible models (20) using a maximum of 4 variables (1 dependent, 3 independent) at a time were used because we felt that 5- to 7-variable models would not be interpretable from either a biological or a management perspective. All variables that produced significant 2- and 3-way interactions ($P < 0.05$) then were used in a stepwise logistic regression (BMDPLR, Dixon 1985:330) to determine the best temporal, weather, and lunar conditions in which to survey great horned owls. To avoid incorporating into the models data that were gathered from stations where no owl was present, only stations known to be occupied by an owl were used in the regression analyses. A station was classified as occupied if an owl was heard or seen on 2 or more visits to that station during a given year. Robbins (1970) recommended that 2 contacts of a singing bird recorded in 7 visits to an area provided significant evidence for determining the presence of a breeding territory. We did not use stations where a single contact was made as these contacts may have represented a floating population and not territorial owls. Precipitation was not included in generating the final model because we seldom conducted surveys when it rained or snowed. *P*-values to enter and remove a variable were 0.10 and 0.15, respectively.

RESULTS

We recorded 1,042 contacts of great horned owls from 3 January to 31 May in 1987 and 1988. Mean response time of owls to the broadcast was 5.9 (SE = 0.1 min). Two-hundred sixty-five (25.5%) of the owl contacts occurred during the 2-minute prebroadcast period. Three-hundred twenty-four (31.2%) and 438 (42.2%) of the owl contacts were noted during the 5-minute broadcast and the 5-minute postbroadcast periods, respectively.

The number of owl contacts differed among the 4 monthly time periods ($G = 96.4$, 3 df, $P < 0.001$; Table 1). More owl contacts (40%) were recorded in January than in other months, and the least number of contacts was noted in April–May (8%). Observed owl contacts per monthly time period differed between years ($G = 60.0$, 3 df, $P < 0.001$), with more owls detected than expected in 1987 but not in 1988. Observed and expected owl contacts per monthly time period did not differ between sex classes ($G = 5.5$, 3 df, $P > 0.14$).

The number of owl contacts differed among the 6 daily time periods ($G = 66.1$, 5 df, $P < 0.001$; Table 1). The greatest number of owl contacts (26%) occurred between 0000 and 0159 hours. Fewer owl contacts than expected were recorded in each daily time period between 1600 and 2359, whereas more contacts than expected were observed between 0000 and 0800 hours (Table 1). The number of owl contacts observed during each daily time period varied between years ($G = 105.3$, 5 df, $P < 0.001$) but not between sex classes ($G = 10.6$, 5 df, $P > 0.06$).

The number of owl contacts differed among the 3 wind categories ($G = 98.4$, 2 df, $P < 0.001$; Table 1). Most owl contacts (81%) were noted when there was no detectable wind (Beaufort scale = 0), despite 32% of the survey

Table 1. Survey effort and observed versus expected number of owl contacts relative to 2 temporal, 3 weather, and 1 lunar variables in south-central Pennsylvania from January to May, 1987 and 1988.

Variable	Effort[a] (%)	Observed number of owl contacts	Expected number of owl contacts
Month			
January	938 (29.8)	420 (40.3)	310.5
February	1,092 (34.6)	350 (33.6)	361.5
March	580 (18.4)	187 (17.9)	191.7
April/May	540 (17.1)	85 (8.2)	178.2
Daily time period			
1600–1959	491 (15.1)	126 (12.1)	157.3
2000–2159	729 (22.4)	179 (17.2)	233.4
2200–2359	719 (22.1)	196 (18.8)	230.3
0000–0159	672 (20.6)	267 (25.6)	214.7
0200–0359	454 (14.0)	197 (18.9)	145.9
0400–0800	179 (5.5)	77 (7.4)	57.3
Wind velocity (Beaufort)			
0	2,189 (67.6)	841 (80.7)	702.3
1	537 (16.6)	123 (11.8)	172.5
≥2	514 (15.8)	78 (7.5)	164.2
Percent cloud cover			
0–25	1,928 (59.5)	678 (65.1)	620.0
26–50	134 (4.1)	30 (2.9)	43.1
51–75	149 (4.6)	43 (4.1)	47.9
76–100	1,026 (31.6)	291 (27.9)	330.2
Temperature (°C)			
≤−11	298 (9.2)	127 (12.1)	95.9
−10 to −6	478 (14.7)	210 (20.2)	153.2
−5 to −1	1,200 (37.0)	404 (38.8)	385.5
0 to 5	826 (25.4)	221 (21.2)	264.7
6 to 10	278 (8.6)	53 (5.1)	89.6
≥11	166 (5.1)	27 (2.6)	53.1
Lunar period			
New to first quarter	595 (18.5)	164 (15.7)	192.8
First quarter to full	1,296 (40.3)	491 (47.1)	419.9
Full to last quarter	713 (22.2)	209 (20.1)	231.3
Last quarter to new	612 (19.0)	178 (17.1)	198.0

[a] Total number of visits to individual survey stations.

effort occurring with measurable wind (Beaufort scale ≥1; Table 1). No owls were heard when wind velocity exceeded 19 km/hour. The number of observed owl contacts noted during 3 wind categories differed between years ($G = 15.1$, 2 df, $P < 0.001$) but not between sex classes ($G = 0.2$, 2 df, $P > 0.90$).

The number of owl contacts differed among the 4 cloud cover categories ($G = 15.0$, 3 df, $P < 0.001$; Table 1). More owl contacts than expected were noted when cloud cover was 0–25% (Table 1). In particular, most owl contacts (58%) were noted when percent cloud cover was ≤5%. The number of observed owl contacts during the 4 cloud cover categories did not differ between years ($G = 7.5$, 3 df, $P > 0.60$) or between sex classes ($G = 2.3$, 3 df, $P > 0.50$).

The number of owl contacts differed among the 6 temperature categories ($G = 69.7$, 5 df, $P < 0.001$; Table 1). More contacts occurred when temperatures were between −20 and 20 C. The observed number of owl contacts was greater than expected when temperatures were below 0 C, whereas fewer owl contacts were observed than expected when temperatures were above 0 C (Table 1). The number of owls contacted among temperature categories differed between years ($G = 11.2$, 2 df, $P < 0.004$). No female owl contacts and only 9 (1%) male contacts were noted during rain.

The number of owl contacts also differed among the 4 lunar categories ($G = 20.26$, 3 df, $P < 0.001$). Most owl contacts (47%) occurred in the lunar period of the day following a first quarter moon to and including a full moon (Table 1), and only in this period was the number of observed owl contacts greater than expected. The number of observed owl contacts during the 4 lunar periods differed significantly between years ($G = 22.7$, 3 df, $P < 0.001$); no difference was found between sex classes ($G = 3.3$, 3 df, $P > 0.30$).

Of the 6 different types of responses by owls to the broadcast, 641 (61.8%) contacts were of an owl vocalizing from a distance without presumably approaching the survey station (Table 2). One-hundred five (10.1%) owls vocalized before approaching the station. Twenty-seven (2.6%) owls were sighted, 17 (1.6%) of which approached the station before vocalizing.

Response type was dependent on visit number, with the greatest number of contacts occurring during the initial visit (i.e., visit 1) to a survey station compared to all other visits (i.e., visits 2–7) ($G = 89.0$, 30 df, $P < 0.001$). Response type was not associated with sex class ($G = 8.3$, 4 df, $P = > 0.10$).

Response type was associated with monthly time period ($G = 75.3$, 15 df, $P < 0.001$; Table 2). One-hundred twenty-five (47%) of the contacts during the prebroadcast period occurred in January. Response type also was associated with daily time periods ($G = 75.0$, 25 df, $P < 0.001$; Table 2). One-hundred fifty-six (58%) of all contacts in the prebroadcast period occurred between 0000 and 0359 hours, and 386 (60%) contacts between 2200 and 0359 hours were those of owls responding without approaching the broadcast.

Table 2. Number of owl contacts for response types made during 4 monthly and 6 daily time periods in south-central Pennsylvania from January to May, 1987 and 1988.

Variable	Response type[a] 1	2	3	4	5	6
Month						
January	125	0	11	5	274	1
February	64	2	57	6	218	3
March	59	1	21	3	103	1
April–May	18	1	16	3	46	0
Daily time period						
1600–1959	14	0	11	7	95	0
2000–2159	37	2	21	1	116	1
2200–2359	35	0	21	3	134	2
0000–0159	81	1	20	4	162	0
0200–0359	75	1	24	2	90	2
0400–0800	24	0	8	0	42	0

[a] Response types: 1 = spontaneous vocalization prior to broadcast, 2 = approached but did not vocalize, 3 = vocalized before approaching, 4 = approached then vocalized, 5 = vocalized but did not approach, and 6 = flushed from area.

Numbers of owl contacts at stations occupied by great horned owls were associated ($P < 0.001$) with monthly time period (MONTH), daily time period (HOUR), temperature (TEMP), and wind velocity (WIND). In contrast, the numbers of owl contacts at these stations were not related to percent cloud cover (CLOUD) ($P > 0.16$) or lunar period (LUNAR) ($P > 0.52$). There was no interaction ($P > 0.99$) between CLOUD and LUNAR. However, 2-variable interactions ($P < 0.05$) were observed between LUNAR and MONTH and between LUNAR and WIND, with the greatest percentage of contacts noted near a full moon regardless of month or wind conditions, thereby suggesting that lunar period had an effect on owl contacts. For example, more owl contacts were observed between the first quarter and last quarter moon in April–May and when wind velocity was >5 km/hour than during other lunar periods during the same monthly time and wind conditions (conditions when fewer contacts were generally made). Other significant 2-variable interactions were MONTH and HOUR, MONTH and TEMP, WIND and HOUR, and WIND and TEMP.

Four variables (WIND, HOUR, MONTH, LUNAR) were included in the final logistic model. The data were best fit by the model: WIND, HOUR, MONTH, LUNAR, WIND × HOUR, MONTH × LUNAR, MONTH × HOUR ($G = 189.2$, 240 df, $P > 0.99$). Based on these 4 variables, predicted probabilities of an owl contact ranged from 0.011 to 0.733 (details of probabilities provided in Morrell and Yahner 1990). Twenty-five (11.3%) of the 222 combinations of variables had a high (>0.50) predicted probability of hearing a great horned owl when an owl was present at the station (≤0.8-km radius). Of the high predicted probabilities, 48% occurred during January, 88% between midnight and 0800 hours, 92% with no wind, and 36% during the period following a first quarter moon to and including a full moon. In contrast, 80 (36%) of the combinations had low (≤0.20) predicted probabilities. Of these, 36% occurred during April–May, 69% between 1600 and 2359 hours, and 85% with measurable winds. Sixty-seven (30%) of the combinations with very low (≤0.10) probabilities occurred from the day following a last quarter moon to and including a new moon.

DISCUSSION

Although we obtained owl contacts under a variety of temporal, weather, and lunar conditions, great horned owl contacts were more likely after midnight in January when temperatures were relatively low and wind velocities were minimal. January coincides with the time when most great horned owls in Pennsylvania have established pair bonds and are territorial (Bent 1938, Austing and Holt 1966).

Because sound travels farther in a more dense than in a less dense medium, vocalizations would be more effective in colder air. Thus, vocalizations given by owls in early morning (e.g., midnight to 0400 hours), when temperatures are cooler and wind is calmer, would suffer less sound attenuation than those given at warmer, windier times.

Wind and rain significantly reduced the number of owl contacts in our study. We noted that our ability to hear owl vocalizations was seemingly impaired when winds exceeded 4.8 km/hour. As wind velocity increases, a "sound shadow" can be created, resulting in a marked attenuation of sound with greater distance (Richards 1981). Attenuation also can be increased during rain because sound can be absorbed by water molecules and because noise created by rainfall probably makes it more difficult to hear owl vocalizations. Similarly, Richards (1981) stated that sounds created by rain, including the noise of water dripping off leaves after a rain, can influence the ability of an observer to survey singing birds accurately.

Our finding that more great horned owls were contacted per given survey effort between the day following a first quarter moon to and including a full moon than during other lunar phases and when cloud cover was less than 50% suggests that bright moonlit nights influenced the probability of owl contacts. Further, owls also were more likely to approach the broadcast on clear nights during a first quarter to and including a full moon than during other conditions. In contrast, Smith et al. (1987) reported that eastern screech-owls (*Otus asio*) were more reluctant to approach a broadcast of a conspecific call, and responses were for a shorter duration on a clear moonlit night than on a dark, cloudy, or foggy night. As in great horned owls, boreal (*Aegolius funereus*) and northern saw-whet owls (*A. acadicus*) readily vocalize on moonlit nights, but the influence of moonlight on incidences of vocalizations in these owls is difficult to assess (Armstrong 1973). Palmer (1987) suggested that in years when calling activity of boreal and saw-whet owls is at a low level, owls might be stimulated more by increased moonlight than in years when calling activity is high. Similarly, he found that the onset of calling during a breeding season by both boreal and saw-whet owls was associated with the presence of a full moon.

We obtained more contacts during the first visit to a given survey station than during subsequent visits to that station. This suggests that owls either habituated to the broadcast or were more likely to respond earlier in the breeding season than later as a function of the chronology of breeding activity. Austing and Holt (1966) stated that great horned owls seldom vocalize while eggs are in the nest, and Peterson (1979) noted that territorial hooting in Wisconsin ended by mid-February. Thus, we believe that per unit effort, February is too late in the breeding season to solicit responses of great horned owls to broadcasts of conspecific calls in Pennsylvania and perhaps at similar latitudes. Conversely, the high numbers of owl contacts per unit effort noted in January indicate that this is the time of the breeding season when surveys at this latitude should be conducted. A greater occurrence of vocalizations given by owls prior to the broadcast during January compared to other months supports the contention that owls were more vocal earlier in the breeding season than later.

Recommended Survey Technique

In future surveys of great horned owls, we recommend that wildlife managers give consideration to temporal, weather, and lunar conditions when conducting surveys. When possible, we recommend that surveys be conducted relatively early in the breeding season, preferably after midnight, on nights without precipitation (rain or snow), and when winds are consistently <4.8 km/hour (Morrell and Yahner 1990). Additionally, an effort should be made to conduct surveys on nights with clear skies during a waxing second quarter to and including a full moon.

When manpower and equipment are available, repeated surveys along a route would be appropriate and could be used to estimate the probability of detecting an owl, which can be used to "adjust" for the variability that occurs from count to count (M. Fuller, U.S. Fish and Wildl. Serv., Laurel, Md., pers. commun.). Further, the number of repeat surveys needed to optimize survey efficiency is unknown and should be examined; when determining the number of surveys needed, investigators should take into account that owls more likely respond during initial visits rather than during subsequent visits to a broadcast station. To avoid contacting owls that had not yet established territories, we began our surveys in January. However, we recommend that future investigators test whether surveys should begin in December or sooner. Similarly, further research is needed to determine the optimal length of survey routes, and how far apart broadcast stations should be.

SUMMARY

Detection of great horned owls, using broadcasts of conspecific calls, was examined in relation to temporal, weather, and lunar variables in south-central Pennsylvania from January to May in 1987 and 1988. Great horned owls were more likely to be contacted on calm nights in January, between midnight and 0600, and during a waxing moon. We also recommended a standardized survey technique for monitoring the long-term status of great horned owls using broadcasts of conspecific vocalizations. Great horned owl surveys should be conducted early in the breeding season, after midnight, and on calm nights with no precipitation.

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LITERATURE CITED

ARMSTRONG, E. A. 1973. A study of bird song. Dover Publ. Inc., New York, N.Y. 343pp.

AUSTING, G. R., AND J. B. HOLT, JR. 1966. The world of the great horned owl. J. B. Lippincott Co., New York, N.Y. 158pp.

BENT, A. C. 1938. Life histories of North American birds of prey. Part 2. U.S. Natl. Mus. Bull. 170. 482pp.

BRAUN, E. L. 1950. Deciduous forests of eastern North America. Hafner Press, New York, N.Y. 596pp.

BRENNER, F. J., AND D. KARWOSKI. 1985. Vocalizations as an index of abundance for the great horned owl (*Bubo virginianus*). Proc. Pa. Acad. Sci. 60:129–130.

DIXON, W. J., editor. 1985. BMDP statistical software. Univ. California Press, Berkeley. 734pp.

FULLER, M. R., AND J. A. MOSHER. 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. Natl. Wildl. Fed., Washington, D.C.

GIFFORD, C. L., AND R. WHITEBREAD. 1951. Mammal survey of south central Pennsylvania. Pa. Game Comm., Fed. Aid Wildl. Restor. Final Rep., Proj. 38-R. 75pp.

GOODRICH, L. J., AND S. E. SENNER. 1989. Recent trends of wintering great horned owls (*Bubo virginianus*), red-tailed hawks (*Buteo jamaicensis*) and two of their avian prey in Pennsylvania. J. Pa. Acad. Sci. 62:131–137.

LYNCH, P. J., AND D. G. SMITH. 1984. Census of eastern screech-owls (*Otus asio*) in urban open-space areas using tape-recorded song. Amer. Birds 38:388–391.

MCGARIGAL, K., AND J. D. FRASER. 1984. The effects of forest stand age on owl distribution in southwestern Virginia. J. Wildl. Manage. 48:1393–1398.

MILLER, L. 1930. The territorial concept in the horned owls. Condor 32:290–291.

MORRELL, T. E., AND R. H. YAHNER. 1990. Status and habitat characteristics of the great horned owl in Pennsylvania. Final Rep., School of Forest Resources, The Pennsylvania State Univ., University Park. 130pp.

PALMER, D. A. 1987. Annual, seasonal, and nightly variation in calling activity of boreal and northern saw-whet owls. Pages 162–168 *in* R. W. Nero, R. J. Clark, R. J. Knapton, and R. H. Hamre, eds. Biology and conservation of northern forest owls: symposium proceedings. U.S. For. Serv. Gen. Tech. Rep. RM-142.

PETERSON, L. 1979. Ecology of great horned owls and red-tailed hawks in southeastern Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 111. 63pp.

RICHARDS, D. G. 1981. Environmental acoustics and censuses of singing birds. Pages 297–300 *in* C. J. Ralph and J. M. Scott, eds. Estimating numbers of terrestrial birds. Cooper Ornithol. Soc. Stud. Avian Biol. 6.

ROBBINS, C. S. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723–726.

SMITH, D. G., A. DEVINE, AND D. WALSH. 1987. Censusing screech owls in southern Connecticut. Pages 255–267 *in* R. W. Nero, R. J. Clark, R. J. Knapton, and R. H. Hamre, eds. Biology and conservation of northern forest owls: symposium proceedings. U.S. For. Serv. Gen. Tech. Rep. RM-142.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry. Second ed. W. H. Freeman and Co., San Francisco, Calif. 859pp.

SPRINGER, M. A. 1978. Foot surveys versus owl calling surveys: a comparative study of two great horned owl censusing techniques. Inland Bird Banding News 50:83–92.

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