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DETECTION AND DENSITY OF THE GREAT HORNED OWL (*BUBO VIRGINIANUS*) IN ARCTIC ALASKA

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Abstract.—Audio playback of vocalizations by conspecifics is commonly used to elicit calls when surveying birds of prey. Methods for call surveys vary widely in their use of silent listening periods, and usually range from 3–15 min in length. We aimed to refine this approach for detecting Great Horned Owls (*Bubo virginianus*) in Arctic Alaska, which is the northernmost limit of their breeding range. We used two playback protocols: protocol 1 entailed uninterrupted playback, whereas protocol 2 interspersed silent listening periods with playback during 12-min surveys. In playback surveys consisting of 166 point counts during the 2017 and 2018 breeding seasons, the probability of detecting a Great Horned Owl was 0.46 (95% CI = ±0.09) with protocol 1 and 0.35 (95% CI = ±0.12) with protocol 2 ($P = 0.18$). The probability of detection rose with the length of the playback: of all owls detected during the 12-min surveys, 23% (95% CI = ±6.4%) responded within the first 3 min, 52 ± 7.6% within the first 6 min, and 80 ± 6.1% within 9 min. Including silent listening periods was not necessary for detecting Great Horned Owls during call surveys. We found no correlation between probability of detection and either cloud cover or wind speed ($P = 0.60$ and $P = 0.28$, respectively). However, we found a negative correlation between temperature and probability of detection ($P = 0.02$). From these surveys, we calculated the density of Great Horned Owls in the Middle Fork Koyukuk Valley, Alaska (approximately 67.589°N, 149.789°W) was 4.2 ± 2.6 owls/km^2 during the winters of 2017 and 2018, which represents the first estimate of density at the northern breeding limit of the species.

Key Words: *Great Horned Owl*; Bubo virginianus; *Alaska*; *Arctic*; *call survey*; *density*; *point count*; *range limit*; *survey methods*.

DETECCIÓN Y DENSIDAD DE *BUBO VIRGINIANUS* EN LA PORCIÓN ÁRTICA DE ALASKA

Resumen.—El empleo de grabaciones con vocalizaciones conespecíficas se usa comúnmente para provocar respuestas cuando se realizan censos de aves de presa. Los métodos para los censos con grabaciones varían ampliamente según el uso de períodos silenciosos de escucha, que usualmente van desde 3 a 15 min de duración. Nuestro objetivo es mejorar este enfoque para detectar a *Bubo virginianus* en la porción Ártica de Alaska, en el límite septentrional de su área de distribución como reproductor. Usamos dos protocolos de reproducción de sonidos previamente grabados: el protocolo 1 implicó la reproducción ininterrumpida, mientras que el protocolo 2 intercaló períodos silenciosos de escucha con periodos de reproducción de sonidos durante períodos de 12 min. En los censos utilizando grabaciones, consistentes en 166 puntos de conteo durante las estaciones reproductoras de 2017 y 2018, la probabilidad de detección de *B. virginianus* fue de 0.46 (95% IC = ±0.09) con el protocolo 1 y de 0.35 (95% IC = ±0.12) con el protocolo 2 ($P = 0.18$). La probabilidad de detección aumentó con la duración de la grabación: de todos los búhos detectados durante los censos de 12 min, el 23% (95% IC = ±6.4%) respondió dentro de los primeros 3 min, el 52 ± 7.6% dentro de los primeros 6 min y el 80 ± 6.1% dentro de los 9 min. La inclusión de períodos silenciosos de escucha no fue necesaria para detectar a *B. virginianus* durante los censos con grabaciones. No encontramos una correlación entre la probabilidad de detección y la cobertura de nubes o la velocidad del viento ($P = 0.60$ y $P = 0.28$, respectivamente). Sin embargo, encontramos una correlación negativa entre la temperatura y la

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probabilidad de detección ($P = 0.02$). A partir de estos muestreos, calculamos que la densidad de *B. virginianus* en el Valle de Middle Fork Koyukuk, Alaska (aproximadamente 67.589°N, 149.789°W), fue de 4.2 ± 2.6 búhos/km^2 durante los inviernos de 2017 y 2018, lo que representa la primera estimación de densidad en el límite reproductivo septentrional de esta especie.

[Traducción del equipo editorial]

INTRODUCTION

Many different survey methods exist to detect the presence of owls across North America (Fuller and Mosher 1987, Takats et al. 2001, Anderson 2007). Researchers use these methods to estimate abundance and density, and locate territories and nests (Anderson 2007). Playing conspecific calls greatly increases the detectability of forest owl species, yet owl response and detectability vary depending on factors such as time of year, weather, habitat characteristics, and observer (Debus 1995, Loyn et al. 2001, Anderson 2007). Although an earlier study of nesting high-latitude Great Horned Owls (*Bubo virginianus*) used audio playbacks to identify nesting territories, the playback methods were not described (Rohner and Doyle 1992).

Call surveys using playback may include a long broadcast of vocalization imitating the usual rate and number of calls that are characteristic of the target species without separate periods of silent listening (Morrell et al. 1991, Martinez et al. 2002). However most protocols for surveying owls use playbacks that alternate broadcast with periods of silent listening (Francis and Bradstreet 1997, Takats et al. 2001, Piorecky and Prescott 2004, Hausleitner 2006). The patterns of playback and silent listening that have been previously employed vary in survey length from 3–15 min, with playback length from 20 sec to 3 min.

Perhaps the most widely used method for detecting owls is Bird Studies Canada's *Guidelines for Nocturnal Owl Monitoring in North America* (Takats et al. 2001). This protocol suggests a 20-sec playback followed by a 3-min silent listening period to detect Great Horned Owls. In a pilot study, we employed this protocol, intending to quickly locate territorial Great Horned Owls in the Middle Fork Koyukuk Valley in Arctic Alaska, but detected far fewer owls than expected. We tried listening for 5–10 min after the 20-sec playback, but still detected very few owls. However, when we began letting the playback run for minutes at a time, we began to detect more owls. Hence, we designed a study with the following aims: (1) to test the effectiveness of different playback methods (i.e., continuous playback vs. playback alternated with silent listening periods) for detecting and enumerating Great Horned Owls, and (2) to estimate the density and abundance of Great Horned Owls in the Middle Fork Koyukuk Valley in Arctic Alaska, at the northern limit of its breeding range.

METHODS

Study Area. Our study took place along the Middle Fork of the Koyukuk River in Arctic Alaska, roughly between latitudes 67° and 68°N, and included what is likely the northernmost known nesting Great Horned Owls (68.01131°N). The study area was bounded to the north by latitudinal tree line at approximately 68.1°N, approximately 2 km north of Nutirwik Creek. It extended from this latitude southward 106 km along the Dalton Highway to Cathedral Mountain (Fig. 1).

Flowing south out of the Brooks Range, the Middle Fork of the Koyukuk River creates a well-defined area of nesting habitat for Great Horned Owls, where trees are large enough for roosting and nesting in the lower elevation areas of the drainage. Trees in these drainages were mostly black and white spruce (*Picea mariana* and *P. glauca*), sometimes infested with spruce broom rust (*Chrysomyxa* sp.), which created structures in which Great Horned Owls could nest. In some areas throughout the study site, the Koyukuk River is lined with cliffs as well as trees, and we found owls nesting on these cliffs as well (M. Reynolds and K. Kielland unpubl. data). The site is accessible by the Dalton Highway, which parallels the Koyukuk River and the Trans-Alaska Pipeline System, and runs through much of the Great Horned Owl habitat on its way to the oil fields of Prudhoe Bay. Owls also nested on the pipeline structures throughout the study area (M. Reynolds and K. Keilland unpubl. data). The area lies adjacent to the southeastern border of Gates of the Arctic National Park, and includes the small communities of Coldfoot and Wiseman, Alaska.

Survey Locations and Estimation of Owl Density and Abundance. Using the Dalton Highway as a transect, we spaced survey locations at approximately 1.6-km intervals (Morrell et al. 1991, Takats et al. 2001), where pullouts were available to safely avoid

Figure 1. Map of the study area, including the communities of Wiseman and Coldfoot, Alaska. The Dalton Highway was used as a transect between Cathedral Mountain and latitudinal tree line north of Nutirwik Creek. The large-scale map shows the location of the study area in Alaska.

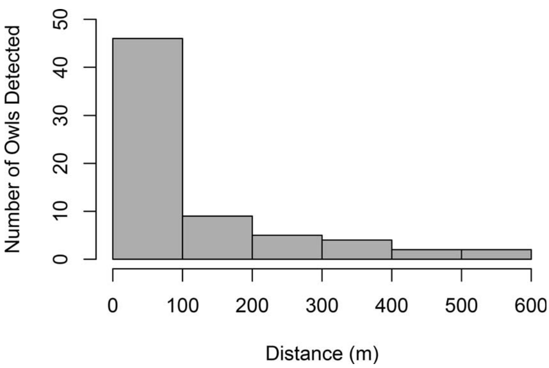

Figure 2. The number of initial Great Horned Owl detections at each distance throughout February 2017 and April 2018 call surveys, Middle Fork Koyukuk Valley, Alaska.

truck traffic servicing Prudhoe Bay. The transect extended from milepost 168 (Cathedral Mountain) to milepost 234 (north of Nutirwik Creek), stretching approximately 106 km with the northernmost survey location at latitudinal tree line. Because the radius of each call survey was 600 m (the farthest estimated detection distance during the study), the transect width measured 1.2 km, for an overall survey area of 127 km^2. Sections of road considered dangerous or under construction were not surveyed, which resulted in 56 stops along the transect, each with a detection area of 1.1 km^2, for a total area surveyed of 63.6 km^2. We used the statistical programs Distance (Thomas et al. 2010) and R (RStudio Team 2015) to estimate population size and density using the equations:

$$N = \frac{nA}{ap} \text{ and } D = \frac{N}{A}$$

where N is the population estimate, n is the number of individuals observed, A is the total area of the study site, a is the area surveyed, p is the probability of detection, and D is density. We calculated probability of detection p by creating a histogram of the frequency of detection distances, and dividing the area under the curve of best fit by the overall area of the histogram (Fig. 2). These methods for estimating density in avian populations are particularly useful where a small proportion of the population may be detected, and where terrain is difficult to navigate, such as in the Brooks Range during winter nights (Buckland et al. 2001, Broekema and Overdyck 2012).

Playback Surveys. Call surveys began at least 30 min after sunset, and ended at least 30 min before sunrise (Takats et al. 2001). Surveys were not conducted in sustained precipitation or when wind speeds were greater than 5 m/sec (>3 on the Beaufort scale) because owls may reduce their calling rates and are more difficult to hear during high wind or precipitation (Richards 1981, Palmer 1987, Morrell et al. 1991). We conducted playback call surveys over the course of 5–6 nights at all locations three times in 2017–2018. In 2017, we conducted call surveys during the last week of January, and in the last week of February before Great Horned Owls began nesting, when we predicted they would be most vocal (Rohner et al. 2001); they began nesting in mid-March during the study (M. Reynolds and K. Kielland unpubl. data). Because the amount of exposures to a playback in a given season can affect response rate, we waited until the spring of 2018 to conduct a call survey during the nesting period (the first week of April; Morrell et al. 1991). This waiting period was intended to minimize the effects of owls becoming habituated to the playback, hence altering their response.

We obtained the playback recording from the Xeno-canto archives (Xeno-canto 2018), and chose a recording of a male and female, subspecies *Bubo virginianus lagophonus* (Weidensaul 2015). The recorded pair takes turns singing back and forth for a total of two times each before the recording repeats. Sex was distinguished by noting the number of hoots and the pitch of each song; male songs typically are lower pitch and consist of fewer hoots (typically 4–5 hoots) than female songs (typically 6–9 hoots; Kinstler 2009). We broadcast the playback using a FoxPro Predator Call megaphone, at a volume between 90–110 dB (Fuller and Mosher 1987).

Each survey was conducted by a single observer, and an assistant controlling the megaphone 25–50 m away from the observer to aid with distance estimation. At each stop, the observer waited for 30–60 sec of silent listening before the survey began. If the observer heard a Great Horned Owl during this time, it was considered "unsolicited" calling at time zero, before the playback survey began. Each survey took 12 min once the first broadcast began. The initial playback protocol was randomly selected, then the two protocols were alternated at each stop. Our playback protocols included (1) protocol 1: the playback was broadcast for 12 min without pauses, and (2) protocol 2: the playback was broadcast for 3 min, paused for 2 min, broadcast for 3 min, paused

Table 1. Detection of Great Horned Owls in call playback surveys during different months in 2017–2018, Middle Fork Koyukuk Valley, Alaska. Number of owls detected during each month, the proportion of point counts where owls were detected, the average number of owls detected/point count, the average number of owls/point count only in sites where owls were detected, the average time of first detection, and the percent of each sex detected are shown. Means and 95% CIs shown.

Month Year	No. Point Counts	Points with Owls Detected	% Points with Owls Detected	No. Owls	% Female	% Male	% Unknown Sex	Avg. No. Owls/ Point	Avg. No. Owls/Point Where Detected	Avg. Time of First Detection (min)
Jan. 2017	56	27	48	52	44	35	21	0.93 ± 0.34	1.96 ± 0.49	6.0 ± 1.32
Feb. 2017	55	19	35	32	28	25	47	0.58 ± 0.24	1.74 ± 0.43	7.4 ± 1.79
Apr. 2018	55	24	44	37	35	59	5	0.67 ± 0.24	1.50 ± 0.36	7.5 ± 0.87
Total	166	70	42	121	37	40	23	0.73 ± 0.16	1.73 ± 0.25	6.9 ± 0.81

for 2 min, and broadcast for 2 min, for a total survey length of 12 min.

When the observer detected an owl, both she and the assistant marked a point at their location in ArcGIS (Esri 2011) on a tablet, and drew a vector in the direction of the owl. Where the vectors crossed, we estimated the owl's approximate location, and used ArcGIS to measure the owl's estimated distance from the observer. We discontinued the playback with the detection of the first Great Horned Owl, and spent the remaining time listening for additional individuals. Detections were either aural or visual or both. We recorded our estimated distance to the first observation. The same single observer recorded the number of Great Horned Owls detected, the time of first detection, and the sex of the individuals detected. To avoid double-counting, we were careful to count only individuals that were not likely to have been detected in a previous point-count. Permits for the field study were obtained through the Alaska Department of Fish and Game and the Institutional Animal Care and Use Committee (Protocol #1010807) under Principal Investigator Knut Kielland.

Measurements of Cloud Cover, Wind Speed, and Temperature. We ranked cloud cover on a scale of 1 to 4, where 1 = 0–25% cloud cover, 2 = 26–50% cloud cover, 3 = 51–75% cloud cover, and 4 = 76–100% cloud cover. We used the Beaufort Scale to assign wind speeds (World Meteorological Organization 1970), and a thermometer to record ambient temperature.

Statistical Analyses. We calculated the probability of detecting a Great Horned Owl by dividing the total number of point counts where at least one owl was detected by the total number of point counts performed. We calculated this probability for all point counts using protocol 1, all point counts using protocol 2, and for all point counts combined. We used a binomial regression fit as a generalized linear model to compare the probability of detecting a Great Horned Owl with protocol 1 vs. protocol 2.

We used Bartlett's test to test for equal variance among months (January, February, April) for the time of first detection and the number of Great Horned Owls detected each month. Where Bartlett's test showed equal variance, we used one-way ANOVAs to test for differences; where Bartlett's test showed unequal variance, we used Kruskal-Wallis rank sum tests.

We used a generalized linear model with binomial regression to test for a relationship between the likelihood of detection and environmental covariates: wind speed, cloud cover, temperature, and protocol type.

RESULTS

We conducted a total of 166 point counts through the three survey sessions ($n = 56$ in January 2017, $n = 55$ in February 2017, $n = 55$ in April 2018). We detected Great Horned Owls in 70 (95% CI = ±7.67) of 166 point counts (42%; Table 1). Across all point counts, we detected a total of 121 Great Horned Owls, an average of 0.73 (95% CI = ±0.16) Great Horned Owls per count. At point counts where at least one Great Horned Owl was detected, we averaged 1.73 owls (95% CI = ±0.23) per count: 37% female, 40% male, and 23% unknown sex. Where we detected Great Horned Owls, the average time to first detection time was 6.88 min (95% CI = ±0.81 min) after the playback began (Table 1).

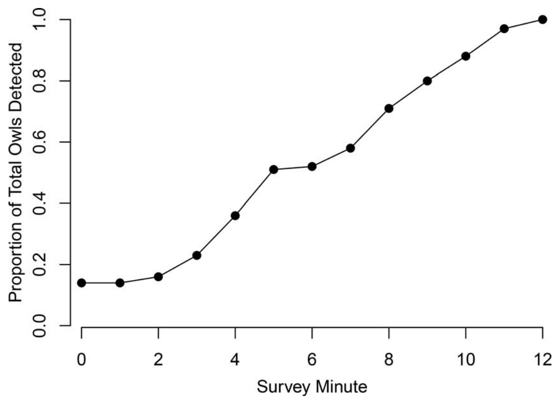

Figure 3. Rate of Great Horned Owl detection throughout 166 call surveys in 2017 and 2018, Middle Fork Koyukuk Valley, Alaska.

Protocol 1 Versus Protocol 2. The probabilities of detecting a Great Horned Owl with protocol 1 (without pauses) and protocol 2 (with pauses) were 0.46 (95% CI = ±0.09) and 0.35 (95% CI = ±0.12), respectively. The binomial regression fit as a generalized linear model indicated this difference in the probability of detection was not significant ($P = 0.18$). Because we found no significant difference between protocols, we pooled data from both protocols in the following analyses.

Detections by Month, Cumulative Detection Rate, and Weather. *Differences by month.* Bartlett's test for equal variance among survey months showed equal variance for the time of first detection ($\chi^2 = 1.99$, df = 2, $P = 0.3697$), so a one-way ANOVA was appropriate. The time of first detection of Great Horned Owls (per point count) did not differ among January, February, and April (one-way ANOVA; $F = 1.42$, df = 2, $P = 0.25$).

Bartlett's test showed unequal variance in the number of Great Horned Owls detected each month ($\chi^2 = 14.49$, df = 2, $P = 0.001$), so nonparametric testing was indicated. A Kruskal-Wallis rank sum test indicated that the number of Great Horned Owls detected did not differ among the three survey months ($\chi^2 = 3.47$, df = 2, $P = 0.18$). Because these survey parameters did not differ among months, data from all months (as well as both protocols) were included in the following analyses.

Cumulative detection rate. The number of Great Horned Owls detected increased with the length of the playback. Fourteen percent (95% CI = ±5.3%) of all Great Horned Owls were detected at time zero (calling without playback elicitation). Considering the total number of Great Horned Owls detected during the 12-min point count as 100%, 23% of owls responded within 3 min (95% CI = ±6.4), 52% within 6 min (95% CI = ±7.6), and 80% within 9 min (95% CI = ±6.1; Fig. 3).

Cloud Cover, Wind Speed, and Temperature. We found no effect of cloud cover ($P = 0.60$) or wind speed ($P = 0.28$) on probability of detection. However, we did find a negative correlation between temperature and probability of detection ($P = 0.02$, $\beta_{temp} = -0.07$).

Abundance and Density. Using the detection-distance relationship (Fig. 2), we calculated the probability of detection p per call survey occasion to be 0.15; we included only February and April surveys because distances were not recorded in all January surveys. In January, we detected a total of 52 individuals in 56 point counts, for an overall abundance estimate of 655 (95% CI = ±176) Great Horned Owls in the survey area. February and April surveys detected 32 and 37 individuals respectively in 55 point counts, for abundance estimates of 436 (95% CI = ±283) and 490 (95% CI = ±166) total Great Horned Owls, respectively. Overall population estimate was 527 (95% CI = ±129) owls. Density estimates for January, February, and April were 5.1 (95% CI = ±1.39), 3.4 (95% CI = ±2.22), and 3.8 (95% CI = ±1.31) Great Horned Owls per km^2, respectively. The average density across all survey months was 4.1 Great Horned Owls per km^2 ($z = 4.302$, 95% CI = ±2.63).

DISCUSSION

With the uninterrupted playback survey protocol, we detected Great Horned Owls at 46% of survey locations, compared to 35% of survey locations when we used playback incorporating silent listening periods. In a study of forest owl detectability in southeast Alaska targeting Western Screech Owl (*Megascops kennicottii*), Northern Saw-whet Owl (*Aegolius acadicus*), and Barred Owl (*Strix varia*), Kissling et al. (2010) noted that 48% of these forest owls responded during 1-min silent listening periods, whereas 52% responded during the 30-sec periods of playback. The authors did not discuss this result in depth, but it suggests that these forest owls are at least as likely to respond during playback as compared to silent intervals. Alongside the myriad protocols that alternate silence and playback (Morrell et al. 1991, Debus 1995, Francis and Bradstreet 1997, Takats et al. 2001, Hausleitner 2006, Kissling et al. 2010, Ibarra et al. 2014), we suggest that continuous playback for Great Horned Owl surveys may be appropriate and may increase detection rate, though this needs further study.

We found a marked increase in detection as the survey playback lengthened, with 23% of owls responding within 3 min, 52% by 6 min, and 80% within 9 min. Without the variable introduced with silent listening periods, one could use point counts without silent listening periods to estimate how many Great Horned Owls may have gone undetected during point counts of shorter time periods. We used a survey length of 12 min, considering this to be the maximum amount of time we could allot to each point count and still complete survey transects within 1 wk. Point counts of longer lengths could help determine the time at which detection rates reach a plateau, which may help researchers be more confident that they have detected a more complete proportion of the population.

Morrell et al. (1991) observed that Great Horned Owl detections in Pennsylvania significantly changed with wind speed, cloud cover, and temperature. They noted that no Great Horned Owls were detected when wind speed exceeded 5 m/sec. For that reason, we only conducted surveys when wind speed was less than 5 m/sec; and within this constraint, wind speed did not correlate with probability of detection ($P = 0.28$). Morrell et al. (1991) detected the greatest number of Great Horned Owls when cloud cover was between 0–25%. We did not see a correlation between detection and cloud cover in this study ($P = 0.60$), which may partially be explained by the fact that nearly all surveys fell on nights when cloud cover was <25% (M. Reynolds unpubl. data).

Morrell et al. (1991) reported an increase in detections when temperatures were below freezing (between 0°C and –20°C), and a decrease in detection when temperatures were above freezing. During our study temperatures never rose above freezing (range –4°C to –39°C). Within these below-freezing temperatures, the number of owls detected increased with lower temperatures. Although air temperature, relative humidity, sound frequency, and air pressure influence the propagation of sound in a complex, non-linear fashion (Attenborough 2007), temperature inversions caused by cold winter conditions tend to propagate sound over longer distances (Ingard 1953, International Organization of Standardization 1993). Therefore, observers may have a better chance of detecting hooting owls on colder nights when sounds may propagate further. Owls may also favor hooting during colder nights to minimize the loss of sound transmission (Wiley and Richards 1978, Endler 1992). Further study is needed to assess the relationship between temperature and detection of Great Horned Owls.

Although we observed no statistical difference in the detection rate between the three survey months, we noted other differences. In February surveys, we detected Great Horned Owls as far as 600 m from the survey point. In the February surveys alone, we first detected 13 of the 32 Great Horned Owls at a distance of >200 m. During the April surveys, however, we first detected all 37 Great Horned Owls within 200 m of the survey point. This suggests that during the April surveys, Great Horned Owls tended to move closer to the caller before being detected. Due to the nocturnal nature of these surveys, we often could not see whether owls flew toward us before announcing their presence; however, on several point counts in April, we noted Great Horned Owls silently flying toward the audio lure before beginning to call (M. Reynolds unpubl. data).

The abundance and density estimates produced in this study may be biased high for the Great Horned Owl population we surveyed because the probability of detection (*p*) assumes that playback does not influence the spatial distribution of the species across the landscape. This spatial bias should be taken into account in all future abundance and density estimates for this species. The use of autonomous audio recording units such as Song Meters (Wildlife Acoustics, Maynard, MA, USA) could be an expensive solution to eliminate this bias by recording unsolicited calls without altering spatial distribution. The month the survey is conducted could also influence this bias. In February we detected Great Horned Owls at the maximum detectable distance. Thus, the bias was notable only in the April survey, which occurred after nests were initiated; because beginning to hoot from the nest could give away the nest location, nesting owls might change their location before responding to a call.

Apparent density of Great Horned Owls was highest in January, compared to February and April. Differences in density estimates could be due to several factors. First, based on the findings of the Kluane Project (Rohner et al. 2001), we expected Great Horned Owls at this latitude to be most vocal and territorial in late January, before nesting. January was also the first period of call surveys in the study and Morrell et al. (1991) noted that response rate can decrease with subsequent exposures to a playback. The presence of non-territorial floaters in the population could also influence the higher apparent density of the January surveys (Rohner 1997). Rohner (1997) estimated that through immigration, non-territorial floaters can compose up to 50% of the population during peak densities of prey. The population of snowshoe hares (*Lepus americanus*), the Great Horned Owl's primary prey at this latitude (M. Reynolds and K. Kielland unpubl. data), was indeed high during this study (3–5 hares/ha; C. Montgomerie pers. comm., K. Kielland unpubl. data), and possibly led to an increased presence of floaters. Presence of these floaters can delay detection of population declines due to temporarily increased numbers, and could be another factor in overestimating abundance and density (Rohner 1997).

Breeding Bird Survey (BBS) data from the contiguous states indicates a 33% decline in Great Horned Owls between 1966 and 2015 (Sauer et al. 2017), though as a caveat, we note that most raptors are poorly surveyed by BBS. Although Great Horned Owls are considered a species of least concern, this alarming trend calls for accurate and streamlined sampling methods to detect population changes of this top predator across its bicontinental range. We recommend standardizing call survey methods through removal of silent listening periods, and recording the time of first response to help estimate the percent of Great Horned Owls detected. We also recommend further research on the vocal response of non-territorial floaters in the population to gain improved estimates of density and abundance.

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Literature Cited

Anderson, D. (2007). Survey techniques. In Raptor Research and Management Techniques (D. M. Bird and K. L. Bildstein, Editors). Hancock House Publishers Ltd, Surrey, BC, Canada, and Blaine, WA, USA. pp. 89–96.

Attenborough, K. (2007). Sound propagation in the atmosphere. In Springer Handbook of Acoustics (T. D. Rossing, Editor). Springer, New York, NY. pp. 113–147.

Buckland, S., D. Anderson, K. Burnham, J. Laake, D. Borchers, and L. Thomas (2001). Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Broekema, I., and O. Overdyck (2012). Distance sampling to estimate densities of four forest bird species during multi-species surveys. New Zealand Ecology 36:353–364.

Debus, S. (1995). Survey of large forest owls in northern New South Wales: Methodology, calling behavior and owl responses. Corrella 19:38–50.

Endler, J. (1992). Signals, signal conditions, and the direction of evolution. American Naturalist 139:S125–S153.

Esri (2011). ArcGIS: Release 10. Environmental Systems Research Institute, Redlands, CA, USA.

Francis, C. M., and M. Bradstreet (1997). Monitoring boreal forest owls in Ontario using tape playback surveys with volunteers. In Second International Symposium of Biology and Conservation of Owls of the Northern Hemisphere (J. R. Duncan, D. H. Johnson, and T. H. Nicholls, Editors). Winnepeg, MB, Canada. pp. 175–183.

Fuller, M., and J. Mosher (1987). Raptor survey techniques. In Raptor Management and Techniques Manual (B. A. Giron Pendleton, B. A. Millsap, K. W. Cline, and D. M. Bird, Editors). National Wildlife Federation, Washington, DC, USA. pp. 37–66.

Hausleitner, D. (2006). Inventory Methods for Owl Surveys, Vol. 42. Ecosystems Branch, Ministry of Environment for the Resources Information Standards Committee, Victoria, BC, Canada.

Ibarra, J., K. Martin, T. Altamirano, F. Vargas, and C. Bonacic (2014). Factors associated with the detectability of owls in South American temperate rainforests: Implications for nocturnal raptor monitoring. Journal of Wildlife Management 78:1078–1086.

Ingard, U. (1953). A review of the influences of meteorological conditions on sound propagation. Journal of Acoustical Society of America 25:405–410.

International Organization of Standardization (1993). Acoustics—Attenuation of sound during propagation outdoors. ISO 9613. International Organization of Standardization, Geneva, Switzerland.

Kinstler, K. (2009). Great Horned Owl *Bubo virginianus* vocalizations and associated behaviours. Ardea 97:413–420.

Kissling, M., S. Lewis, and G. Pendleton (2010). Factors influencing the detectability of forest owls in southeastern Alaska. The Condor 112:539–548.

Loyn, R., E. McNabb, L. Volodina, and R. Willig (2001). Modelling landscape distributions of large forest owls as applied to managing forests in north-east Victoria, Australia. Biological Conservation 97:361–376.

Martinez, J., I. Zuberogoitia, J. Colas, and J. Macia (2002). Use of recorder calls for detecting Long-eared Owls *Asio otus*. Ardeola 49:97–101.

Morrell, T., R. Yahner, and W. Harkness (1991). Factors affecting detection of Great Horned Owls by using broadcast vocalizations. Wildlife Society Bulletin 19:481–488.

Palmer, D. (1987). Annual, seasonal, and nightly variation in calling activity of Boreal and Northern Saw-whet Owls. In Biology and Conservation of Northern Forest Owls (R. W. Nero, R. J. Clark, R. J. Knapton, and R. H. Hamre, Editors). Gen. Tech. Rep. 142. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA. pp. 162–168.

Piorecky, M., and D. Prescott (2004). Distribution, Abundance and Habitat Selection of Northern Pygmy and Barred Owls along the Eastern Slopes of the Alberta Rocky Mountains. Alberta Species at Risk Report No. 91. Alberta Sustainable Resources Development, Edmonton, AB.

Richards, D. (1981). Environmental acoustics and censuses of singing birds. Studies in Avian Biology 6:297–300.

Rohner, C. (1997). Non-territorial floaters in Great Horned Owls (*Bubo virginianus*). In Second International Symposium of Biology and Conservation of Owls of the Northern Hemisphere (J. Duncan, D. Johnson, and T. Nicholls, Editors). Winnepeg, MB, Canada. pp. 347–362.

Rohner, C. (1997). Non-territorial 'floaters' in Great Horned Owls: Space use during a cyclic peak of snowshoe hares. Animal Behavior 53:901–912.

Rohner, C., and F. I. Doyle (1992). Method of locating Great Horned Owl nests in the boreal forest. Journal of Raptor Research 26:33–35.

Rohner, C., F. I. Doyle, and J. N. M. Smith (2001). Great Horned Owls. In Ecosystem Dynamics of the Boreal Forest: The Kluane Project (C. J. Krebs and R. Boonstra, Editors). Oxford University Press, New York, NY, USA. pp. 339–377.

RStudio Team (2015). RStudio: Integrated development for R. RStudio, Inc., Boston, MA, USA. http://www.rstudio.com.

Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr., K. L. Pardieck, J. E. Fallon, and W. A. Link (2017). The North American Breeding Bird Survey, results and analysis 1966–2015. Version 2.07.2018. USGS Patuxent Wildlife Research Center, Laurel, MD, USA. https://www.mbr-pwrc.usgs.goc/bbs/bbs.html.

Takats, L. D., C. M. Francis, G. L. Holroyd, J. R. Duncan, K. M. Mazur, R. J. Cannings, and D. Holt (2001). Guidelines for Nocturnal Owl Monitoring in North America. Beaverhill Bird Observatory and Bird Studies Canada, Edmonton, AB, Canada.

Thomas, L., S. Buckland, E. Rexstad, J. Laake, S. Strindberg, S. Hedley, and K. Burnham (2010). Distance software: Design and analysis of distance sampling surveys for estimating population size (Version 7.2). Journal of Applied Ecology 47:5–14. http://distancesampling.org/

Weidensaul, S. (2015). Peterson Reference Guide to Owls of North America and the Caribbean. Houghton Mifflin Harcourt Publishing Company, New York, NY, USA.

Wiley, R., and D. Richards (1978). Physical constraints on acoustic communication in the atmosphere: Implications for the evolution of animal vocalizations. Behavioral Ecology and Sociobiology 3:69–94.

World Meteorological Organization, Commission for Maritime Meteorology (1970). The Beaufort Scale of Wind Force: Technical and Operational Aspects. World Meteorological Organization, Geneva, Switzerland.

Xeno-canto Foundation (2018). Xeno-canto: Sharing bird sounds from around the world. Xeno-canto Foundation and Naturalis Biodiversity Center. https://www.xeno-canto.org/.

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