Field evaluation for playback surveys: species-specific detection probabilities and distance estimation errors in a nocturnal bird community

DOI:10.1080/00063657.2021.1968790

Field evaluation for playback surveys: ~~identification of nocturnal~~ species-specific detection probabilities and distance estimation errors in a nocturnal bird community ~~estimates in an agricultural landscape~~

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Short title: Playback field evaluation

Keywords: binomial GLMM, broadcast experiment, call detection, bird monitoring, elusive birds, owls

Abstract

Capsule: During playback experiments, the distance from the surveyor to the call influences the chances of detection across nocturnal species in farmland and woodland habitats.

Aim: To evaluate how distance affects surveyor detection capability, expressed as the probability of hearing broadcast calls and of estimating their distances correctly, in a nocturnal bird community.

Methods: We conducted a playback field experiment in farmland and woodland areas within an agricultural landscape in winter and summer 2020. ~~Recorded~~ Vocalisations of five elusive species (Little Owl *Athene noctua*, Tawny Owl *Strix aluco*, Long-eared Owl *Asio otus*, Common Nightingale *Luscinia megarhynchos*, Water Rail *Rallus acquaticus*) were broadcast at various distances to a surveyor, who attempted to detect them and, if successful, to classify them into predefined distance zones. ~~were broadcast to a surveyor who attempted to estimate the distance to each call~~. Binomial GLMMs were used to estimate detection probability as a function of distance, and the effects of habitat and season on this relationship.

Results: The distance of the broadcast call from the surveyor had a significant effect on detection probability in both habitats. In woodland, the probability of hearing calls was significantly higher in winter, while estimating distances correctly was generally higher in summer. An increase in field experience improved our detection capability, mainly in terms of distance estimation, whose errors were mostly overestimations. ~~Long-eared Owl was the only species for which estimates were consistently poor.~~

Conclusions: The probability of hearing calls and distance estimation accuracy varied between species. While a 200 m radius around the surveyor fitted better for the Little and Tawny Owl, this was 100 m for the other species. ~~Most Little Owl and Tawny Owl calls were detected within a 200 m radius of the surveyor, while this was 100 m for the other species~~. For a multi-species community-level study, playback surveys are thus likely to be most representative of a 200 m radius surrounding the surveyor where the probability of detection is highest, while estimates of distance from the observer are likely to be inaccurate in most cases. Field evaluations such as this should be implemented prior to actual playback surveys.

Introduction

Playback is commonly used to survey birds as it represents an efficient method to census elusive species ~~thus~~ by improving their detection probability (Hardy & Morrison 2000, Navarro *et al*. 2005, Stermin *et al*. 2017). This technique consists of broadcasting generally conspecific recorded calls in order to elicit their vocal reply (Johnson *et al.* 1981, Worthington-Hill & Conway 2017). This is particularly useful for those species that exhibit territorial behaviour because they will be more inclined to respond in order to defend their territories (Haug & Didiuk 1993, Pilla *et al*. 2018). Relying only on spontaneous vocalisations can be insufficient, because they may limit census performance ~~may be insufficient, thus limiting census performance~~ (Crowe & Longshore 2013). It is known that factors such as habitat, seasonality, time of day and weather can influence response rates during playback surveys (Hardy & Morrison 2000, Currie *et al*. 2002, Polak 2005, Braga *et al.* 2009, Johnson *et al.* 2009). In addition, more technical parameters such as sound amplitude level and surveyor detection ability or experience (Crowe & Longshore 2013, Zuberogoitia *et al*. 2020) are also fundamental as they enable a detectability radius to be defined, which is a threshold distance expressing at what scale bird distributions can be better estimated, i.e. a distance around playback points within which a surveyor has higher probabilities to detect birds. Usually, only responses detected at a distance within the radius are included in the analysis, since it provides some level of security, so that results include most individuals actually occupying a given area ~~which is the maximum distance around playback points that allows surveyors to hear and detect birds. Responses from an estimated distance greater than the selected radius are not considered reliable and are typically excluded from the analysis~~ (Centili 2001, Johnson *et al.* 2009, Bolboacă *et al.* 2015). Therefore, the detectability radius has a key role in minimizing biases. During aural surveys, distance estimation is clearly more difficult than for visual detections and making errors in estimation can consequently bias the results (Marques 2004).

Field evaluations prior to actual playback surveys therefore represent a useful step to adjust the method by setting a fixed distance (and so a radius) calibrated on the surveyor's detection capability in the field (Esclarski & Cintra 2014), where radial distance is a function of the surveyor's ability to estimate bird-surveyor distance and to hear broadcast calls. Experimental trials of this kind can help researchers to conduct playback surveys as accurately as possible. From this perspective, we carried out a field experiment aimed to evaluate the effect of distance on detectability in different habitats within an agricultural landscape, by addressing the following questions:

(i) Does distance influence the surveyor's ability to hear playback calls and to estimate their distances correctly in farmland and woodland?

(ii) Does the effect of distance in woodland have the same effect on detection probability in summer and winter?

In this way, we aimed to understand at what scale nocturnal species detection and distribution can be estimated in this landscape. As target species, we used territorial playback songs/calls of Common Nightingale *Luscinia megarhynchos*, Little Owl *Athene noctua*, Tawny Owl *Strix aluco*, Long-eared Owl *Asio otus* and Water Rail *Rallus acquaticus*. Within our study region, these species form a common bird community with similar elusive habits. These birds are territorial, hard to see, and more active at night. For these reasons, they are frequently censused through playback, especially from dusk and at night (Zuberogoitia & Campos 1998, Schmidt *et al*. 2006, Brambilla & Jenkins 2009, Seoane & Galvàn 2010, Stermin *et al*. 2017). Through our experiment, we attempted to provide a valid insight into the playback method in surveying our target species effectively.

Methods

Study area

The study was carried out in the Piedmont Region, northern Italy. We conducted playback surveys in an agricultural landscape dominated by arable crops and interspersed with small woods, within the Natural Park

'Parco del Po Vercellese-Alessandrino', in the southern part of Vercelli Province. The first site consisted of a typical intensive agricultural landscape close to a wetland area (named 'Riserva Naturale Speciale e Zona di Salvaguardia della Palude di San Genuario', 8°10'54"E, 45°13'7"N) dominated by rice fields, the most important cultivation of the area. The second site was an oak-hornbeam (*Quercus* and ~~*Populus*~~ *Carpinus* species) woodland area (named 'Parco Naturale del Bosco delle Sorti della Partecipanza', 8°16'1"E, 45°13'50"N). Both sites are SCIs (Sites of Community Importance) and ZSPs (Zones of Special Protection under the Birds Directive).

Field survey protocol

We designed the playback field experiment as follows: in each habitat we established one transect with ten points, spaced 200 m apart, and each point was visited eight times (i.e. eight repetitions). At each repetition, one researcher (the 'broadcaster') moved ~~in~~ to a random location around one single surveyor (the 'observer') and broadcastthe whole call sequence (noting the time of broadcast) of all five species. The surveyor stayed fixed at each point and (i) noted the time and species when a call was detected and (ii) estimated playback distances (assigning calls to distance classes of between 0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-500 m and >500 m). At each repetition, the surveyor did not know the location of the broadcaster. We used a handheld GPS (Garmin eTrex 10) to identify survey points and to note the location of each playback made by the broadcaster. We conducted one survey in farmland and one in woodland in winter (between the end of February and the beginning of March 2020); then we repeated a third survey only in woodland in summer (mid-July 2020) to test for a seasonal effect in this habitat. We performed all surveys in good weather conditions (i.e. not on rainy or windy days). Although the target species were nocturnal (Long-eared Owl, Tawny Owl), crepuscular, or more vocally active at night (Water Rail, Little Owl, Nightingale), we carried out the surveys in daylight, partly due to access restrictions, but also to minimise the potential confounding effects of real (rather than ~~recorded~~ broadcast) vocalizations.

We delivered playback using a handheld Bluetooth wireless speaker (Tronsmart Element, T6 Mini) positioned at chest height (Pilla *et al.* 2018), c. 1.6 m above the ground. The device was designed to spread sound at 360° to ensure that vocalisations were broadcast in all directions. The call sequence consisted of territorial vocalisations of the five species, downloaded from the Xeno-canto website (www.xeno-canto.org), which were then uploaded to a smartphone and broadcast with the speaker via Bluetooth. We always maintained the following order for the sequence: Common Nightingale > Water Rail > Little Owl > Long-eared Owl > Tawny Owl. For each species, broadcast calls lasted 30 seconds, without intervals between them. After the whole sequence had been completed, the broadcaster moved to another random location unknown to the surveyor and repeated it. This procedure was carried out eight times for each point (i.e. eight repetitions made in eight random locations for each of the ten points). The start and end of each repetition was notified to the surveyor by text message. Once all the repetitions for a point were completed, the surveyor moved to the next point along the transect.

We adjusted a fixed volume for all broadcasts at a level equivalent to the sound pressure level of natural vocalizations. We used a sound level meter (SLM Meterk MK 09) to set the volume in order to match natural levels: 81 ± 1 dB for Common Nightingale (Kiefer *et al.* 2011); 82 ± 1 dB for Little Owl (Jacobsen *et al.* 2013, Clewley *et al.* 2016); and, 83 ± 1 dB for Tawny Owl (Vrezec & Bertoncelj 2018). We were unable to find information on Water Rail and Long-eared Owl vocalizations, so we respectively set 80 ± 1 dB and 73 ± 1 dB, i.e. relatively low values matching our personal observations of these species relative to the others listed above. We obtained all dB values by positioning the SLM at a distance of 1 m.

Data analysis

We used Garmin BaseCamp software to download location data from the GPS and to calculate real distances between the surveyor and broadcaster. To evaluate the effect of distance on detection probability, we used a mixed modelling approach, fitting binomial generalized linear mixed models (GLMM) to explain the probability ~~to~~ of hearing playback calls (binomial response: 1 = calls heard; 0 = calls not heard) and the probability of estimating distances of those calls that were detected correctly (binomial response: 1 = calls estimated in the correct distance class; 0 = calls not estimated in the correct distance class). Survey point identity was specified as a random effect in order to account for repeated observations from the same point, and real distances, habitat and species were specified as fixed effects. To test for a seasonal effect in woodland, we used the same approach and included season (winter or summer) and the interaction term between Real distance and season. Before modelling, the 'Real distance' variable was scaled. Models were validated using the Hosmer-Lemeshow goodness of fit test (Hosmer & Lemeshow 2000), where a significant test result (as measured by the chi-squared statistic) indicates poor model fit. When this occurred, we used Cook's distance (Cook 1979) to identify and remove potential outliers.

Since we always maintained the same order of species to broadcast calls, there was potential temporal autocorrelation in the probability of detecting a call between species, for both distance estimation and the resulting classification into distance classes, since the observer would have known that the whole broadcast came from the same location (i.e. at the same distance). In other words, after hearing the first call, the surveyor could have been more likely to detect subsequent calls in the sequence, as they would have known what came next. For this reason, GLMMs fitted to the ability to hear playback calls could potentially be affected by non-independence. Therefore, to verify their consistency, we also ran models based o generalized estimating equations (GEEs) that accounted for the potential non-independence by fitting broadcast call order as a temporal correlation structure and defining each broadcast of the five species within a playback repetition as a group that combined point identity and repetition number.

Statistical analyses were carried out using R software (v. 3.6.3; R Core Team 2020). GLMMs were fitted in the lme4 package (Bates *et al*. 2015) and their results visualised with ggplot2 (Wickham 2016). GEE models were fitted in the geepack package (Halekoh *et al*. 2006).

Results

We carried out 1200 broadcasts in total: 400 in farmland (first survey) and 400 in woodland (second survey) in winter, and 400 in woodland in summer (third survey). Real distances ranged between 34.6 and 365.5 m and the number of broadcast calls, correct distance estimates and calls detected varied among distance classes. Estimating playback distances correctly (c. 28 % of broadcasts were estimated in the correct distance band) was more difficult than being able to hear broadcast calls (c. 78 % of calls were detected; **Table 1**).

Effect of distance on detectability in both habitats in winter

The ability to hear playback calls across all species declined significantly with distance (slope = -1.64 ± 0.17, z = -9.69, p < 0.001; **Table S1a**, Appendix). Predicted probabilities of hearing calls were often high at 200 m, especially in woodland, and the easiest species to hear was Little Owl (estimated probability = 0.97), followed by Tawny Owl (0.96), Common Nightingale (0.82), Water Rail (0.81) and Long-eared Owl (0.67; **Figure 1**). At a distance of 300 m, probabilities dropped, particularly for Long-eared Owl, Water Rail and Common Nightingale (respectively 0.14, 0.26 and 0.28 in woodland). Detection probabilities were always significantly higher in woodland than farmland (p < 0.001). The Hosmer-Lemeshow test showed a good model fit (χ^2 = 8.09, *df* = 8, p > 0.05). The GEE model supported the GLMM in that hearing playback calls declined with distance very similarly (slope = -1.61 ± 0.15, w = 110.96, p < 0.001; **Table S1b**, Appendix). The lack of any qualitative difference between the GLMM and GEE results thus suggests that potential temporal autocorrelation between the calls in a given sequence did not affect the conclusions regarding the estimates of probability of hearing calls in relation to distance.

The ability to estimate playback distances correctly for calls that were detected declined significantly with distance ~~at greater distances to the broadcaster~~ (slope = -1.39 ± 0.16, z = -8.56, p < 0.001; **Table S1c**, Appendix). Predicted probabilities of assigning distances to the correct distance band were low: all <18 % at

200 m and <3% at 300 m (**Figure 2**). In woodland at 200 m, the best estimates were associated with Common Nightingale (0.17) and the lowest with Long-eared Owl (0.04). Probabilities were significantly higher in woodland than farmland ($p < 0.01$). The Hosmer-Lemeshow test showed a good model fit ($\chi^2 = 9.40$, *df* = 8, $p > 0.05$).

For detected calls, in the first and second survey, distances estimated wrongly were all overestimation errors, i.e. the surveyor always placed estimates in a distance class further than the correct one. In total, 248 overestimations were made in the first survey and 215 in the second (**Table S2**, Appendix). ~~Errors decreased between the first to the second survey for each species~~ The number of misclassifications declined in consecutive surveys for each species except for the Long-eared Owl (**Table S3**, Appendix).

Seasonal variation in woodland

The effect of distance on the ability to hear playback calls was significant (slope = -1.42 ± 0.19 , z = -7.67, $p < 0.001$; **Table S1d**, Appendix), but did not change between the second and third survey, i.e. there was no difference in slope between winter and summer (parameter estimate = -0.16 ± 0.32, z = -0.5, $p > 0.05$). However, season was significant ($p < 0.001$) and predicted probabilities were higher in winter (**Figure 3**). Little Owl and Tawny Owl were the easiest species to detect, and Long-eared Owl the hardest (respectively 0.97, 0.97 and 0.74 at 200 m in winter). At 200 m, probabilities were generally high, but at 300 m they were always less than 52 % in summer and 72% in winter. The Hosmer-Lemeshow test did not show a good model fit ($\chi^2 = 26.0$, *df* = 8, $p < 0.05$). We investigated this poor model fit by looking for possible outliers ~~i.e. the observations~~ that mostly negatively influenced the model ~~We used Cook's distance approach (Cook 1979)~~ and we dropped the observations (n = 6) which revealed the highest Cook's distance values. This was the minimum number of observations that enabled an improvement in model fit ($\chi^2 = 11.0$, *df* = 8, $p > 0.05$). No qualitative differences were found in the model results (**Table S1e**, Appendix).

Again, the GEE model did not show differences compared to the GLMM, neither in terms of the distance effect on the ability to hear calls (slope = -1.04 ± 0.24 , w = 19.19, $p < 0.001$; **Table S1f**, Appendix) nor in terms of difference in slope between seasons (parameter estimate = -0.45 ± 0.30, w = 2.20, $p > 0.05$).

Overall, playback distances were estimated increasingly erroneously in more distant zones (slope = -0.76 ± 0.12, z = -6.14, $p < 0.001$; **Table S1g**, Appendix) and there was a significant seasonal variation (parameter estimate = -0.58 ± 0.23, z = -2.56, $p < 0.05$). Predicted probabilities were generally higher in summer than in winter (**Figure 4**) and higher at 200 m than 300 m for all species. ~~Probabilities were quite high at 200 m for all species, but they dropped at 300 m~~. Higher probabilities were associated with Little Owl and Common Nightingale (both 0.32 at 200 m and 0.14 at 300 m in summer), while the Long-eared Owl remained the most difficult species to estimate (0.20 at 200 m and 0.08 at 300 m in summer). The Hosmer-Lemeshow test did not show a good model fit ($\chi^2 = 29.0$, *df* = 8, $p < 0.05$). So, as before, we dropped the minimum number of observations (n = 20) with the highest Cook's distance values which enabled to improve the model fit ($\chi^2 = 14.0$, *df* = 8, $p > 0.05$). No qualitative differences were found in the model results, except for an increase in the significance of seasonal variation (parameter estimate = -0.89 ± 0.28, z = -3.16, $p < 0.01$; **Table S1h**, Appendix).

In the third survey, overestimations decreased (from 100 % in both the first and second survey to 64 % in the third), but there were also some underestimations (36 %) which occurred between 0-100 m and 100-200 m. However, the surveyor made in total fewer wrong estimates (n = 139). In fact, no erroneous estimates were made in the two furthermost classes (**Table S2**, Appendix). In relation to species, errors decreased overall (**Table S3**, Appendix).

Discussion

Through this field evaluation, we investigated the effect of distance on surveyor detection capability, expressed in terms of being able to hear playback calls and estimating distances to the calls correctly ~~and~~

~~estimating their distances in the correct distance class~~. Other studies have attempted to evaluate the response distance of elusive birds and the distance from the surveyor (Proudfoot *et al*. 2002, Flesch & Steidl 2007, Bartolommei *et al*. 2012), because its measurement helps to improve detection and determine bird densities. Monitoring nocturnal birds, Puglisi & Bartolommei (2012) estimated the distance of detected birds from the surveyor, selecting four distance classes (<50, 50–100, 100–300 and >300 m). They always detected Long-eared Owl at distances less than 100 m, whereas Little Owl and Tawny Owl were detected across all classes. Such classes were considered by Bartolommei *et al*. (2012), who adopted a 300 m radius in their methods to investigate the presence and distribution of Little Owl and Tawny Owl according to land-use categories in an agricultural landscape of Central Italy. ~~These estimates reflect our own investigation into surveyor's estimation ability~~ Instead, unlike Bartolommei *et al*. (2012), ~~but~~ in our experiment we specifically fitted models to evaluate separately the probability to detect calls and to estimate distances correctly in relation to distance, testing also a seasonal effect.

Some playback field experiments have already been conducted in forested habitats to evaluate distance estimates and their error structure for various songbirds, using known distances. Alldredge *et al*. (2007) used playback songs of several birds (Acadian Flycatcher *Empidonax virescens*, Black-and-white Warbler *Mniotilta varia*, Black-throated green Warbler *Dendroica virens*, Red-breasted Nuthatch *Sitta canadensis*, and Wood Thrush *Hylocichla mustelina*) and found that surveyors had difficulties to identify what was the distance to the bird song at distances beyond 65 m. ~~and found that surveyors could not discriminate between songs at different distances beyond 65 m~~. They also pointed out that, after training, surveyors reduced distance estimation errors. In our approach, we instead used unknown distances, chosen randomly by the broadcaster, and the surveyor was unaware of their location. This had the objective of simulating real situations in the field, when surveyors have to census species that can be anywhere. Moreover, in our study, we considered detection both in terms of the ability to estimate distances and the ability to hear broadcast calls.

The effect of distance on surveyor detection capability

Our results showed that detectability varied due to both species and distance. Our results showed marked variation in detectability as a function of distance between species. The decrease in detectability was especially marked in those species whose calls are low in acoustic intensity. In particular, this was the case for the Long-eared Owl, the hardest species to hear and to estimate distance. This was consistent with our expectations as its territorial call is not very loud. On the contrary, Little Owl and Tawny Owl were the easiest species to detect, thanks to their shrill and more acute vocalisations. Water Rail and Common Nightingale were challenging to detect, but not as difficult as Long-eared Owl, although during the summer survey, Common Nightingale showed estimates as high as those for Little Owl, and Water Rail as high as those for Tawny Owl. Detecting playback calls was less difficult than estimating their distances correctly, but we noted an improvement in both (respectively a c. 20 % and 28 % increase) between the first and the second survey. In woodland, detectability was higher overall. This is a surprising result as we did not expect such a striking difference compared to farmland. Nevertheless, the latter habitat, being an open environment, could have been more influenced by potential background noise (e.g. from roads nearby), which may explain this divergence. Though, we suggest caution in interpreting this difference and more field trials would be useful to better assess this aspect.

The ability to hear playback calls in woodland did not improve during the third survey in summer. The probability of hearing broadcast calls was significantly inferior lower in summer than winter ($p < 0.001$). This can be explained by the likely blocking effect of the dense vegetative structure characterizing woodland in this season. Moreover, in summer this habitat is more disturbed in terms of background sounds: Throughout the summer survey, there was a continuous noise, represented especially by the singing of grasshoppers and Common Blackbirds *Turdus merula*. Together with the thick foliage, sound diffusion was hampered. Therefore, in summer woodland can act as a natural “acoustic barrier”, limiting the surveyor’s ability to hear bird calls (**Figure 5**). Conversely, in winter, there was less acoustic disturbance.

Despite the dense vegetation and background noise, the effect of distance on the ability to estimate playback distances improved significantly in summer, during the last survey. improved in the last survey and

~~varied significantly with season~~. This fact is likely due to an increase in our field experience. After the first survey, we were able to better calibrate estimates and reduce errors, in particular in terms of overestimated distances. For detected calls, distance estimate errors decreased by 8.3 % between the first and second survey and by 19 % between the second and the third. Surveyor experience has already been demonstrated to be a relevant factor affecting bird detection probabilities (Booms *et al*. 2010, Jiguet & Williamson 2010, Johnston *et al*. 2018), including nocturnal species (Zuberogoitia *et al*. 2020). A radial distance of about 200 m, at which playback could be heard, has previously been adopted to census Tawny Owls (Appleby *et al*. 1999). In another case, a distance of 300 m was used for Tawny Owl and Little Owl (Bartolommei *et al*. 2012) as it proved to be the best estimated distance for both species. Detection radius is not a constant value and it varies across studies, because it changes according to target species, habitat and surveyor detection capability (Centili 2001, Esclarski & Cintra 2014, Menq & Anjos 2015, Zuberogoitia *et al*. 2020). Therefore, given these sources of variation, tests like ours should be made before playback surveys.

Based on our results, at 300 m we found that the detection capability was quite weak overall, mainly in terms of the ability to estimate distances correctly. Therefore, we suggest that a 200 m detectability radius should be set as maximum threshold. In our study any inference from playback can only be reliably related to this radial distance around the surveyor, i.e. inferences about our target species should be limited to 200 m because most of the detected calls will be within that distance. For Common Nightingale, Water Rail and Long-eared Owl, which were generally more difficult to detect than Little Owl and Tawny Owl, a radius of 100 m could certainly be a good option. However, for a multi-species community level study, a common cut-off can ease the comparison of results at the same scale among all species. In this case, a 200 m limit would be a reasonable alternative. Distance estimates were, however, generally poor, and for most species the probability of accurately estimating distance was greater than 0.50 only at distances of 100 m or less. ~~Therefore, in our study, distance estimates are inappropriate for the use of distance sampling techniques (e.g. Buckland *et al.* 1993, Neubauer & Sikora 2020), as they are not accurate enough to estimate species density.~~ Distance sampling methodology is an appropriate tool to estimate density when distances to species are known, but it assumes distances to be estimated without errors (Buckland *et al.* 1993), which was not the case in our study. Indeed, errors occur even with wide distance classes and experienced observers (Neubauer & Sikora 2020). We should stress that density estimation was not the purpose of our study. Instead, our goal was an attempt to understand at what scale detection and distribution could be estimated for our target species, which is likely a 200 m radius. At greater distances, detection probabilities became very low.

Based on different study objectives, researchers could carry out field experiments like this for their species of interest, identifying a suitable detectability radius through the evaluation of the two detectability components analysed prior to the actual surveys of the species. We recommend that our methods should be generally considered with more caution for Long-eared Owl, Common Nightingale and Water Rail. We particularly acknowledge that in our study, the component related to distance estimation could not be carried out accurately for these three species without training.

Field experiment timing and potential bias

As we described in methods, we maintained the same order of species calls during the experiment, potentially leading to a non-independence bias among subsequent calls of different species ~~among species~~. However, our results showed that this methodological choice unlikely affected GLMM outcomes. Estimates relative to the effect of distance on detectability did not differ substantially between GLMM and GEE approaches, and the significance levels of variables did not change. This suggests consistency between the two modelling approaches, hence we are confident that this kind of bias did not affect the validity of our analysis regarding the surveyor's ability to hear broadcast calls.

Although the focus of this study was on crepuscular and nocturnal species, the playback experiment was carried out during daytime ~~in daylight~~. This was partly due to access restrictions in some parts of the study area (particularly in rice fields), but also in order to avoid confounding real vocal responses from the study species. Similarly, the experiments started in late winter, when some of our target species are not vocally active or had not yet returned from their wintering areas (in particular Little Owl, Water Rail and Common

Nightingale). In order to make use of these results to inform methods for playback surveys of the target species, the underlying assumption that the performance of the surveyor is not affected by time of day and season needs to be addressed. In terms of the former, we would expect that background noise is likely to be higher in the daytime, both from natural and anthropogenic sources, hence we can consider our estimates to be appropriately conservative (i.e. we expect that performance would be higher at night). In terms of the latter, we did find evidence of seasonal effects in woodland, although these were inconsistent between probability of detection (which was marginally greater in winter) and probability of correct distance estimation (which increased in summer). However, the latter results did not change our overall conclusions regarding methodological recommendations, i.e. that playback surveys are likely to be most representative of a 200 m radius surrounding the surveyor where the probability of detection is highest, while estimates of distance from the observer are likely to be inaccurate in most cases.

Acknowledgements

We are grateful to the Park 'Parco del Po Vercellese-Alessandrino' which allowed the access to their areas and for the availability of bird songs at www.xeno-canto.org. We are also thankful for the very useful comments and suggestions provided by the anonymous reviewer that enabled us to improve our manuscript.

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Appendix

Table S1: ~~model outputs~~ parameter estimates from the binomial GLMM/GEE explaining the ability to hear playback calls and estimate distances correctly

Table S1a. Ability to hear playback calls in farmland and woodland in relation to distance.

Variable	Estimate	Standard error	Z value	P value
Intercept	1.399	0.398	3.511	0.0004
SReal distance	-1.636	0.169	-9.696	< 2e-16
Habitat (Woodland)	1.859	0.513	3.627	0.0003
Species (Little Owl)	2.089	0.458	4.562	5.1e-06
Species (Long-eared Owl)	-0.897	0.351	-2.561	0.010
Species (Tawny Owl)	1.720	0.430	4.001	6.3e-05
Species (Water Rail)	-0.065	0.358	-0.181	0.856

Model outcome showing fixed effects. ~~Model formula: *Regis heard ~ SReal distance + Habitat + Species + (1|Point)*, where *Regis heard* stands for surveyor ability to have heard or not playback calls and *Real distance* was scaled (*S*).~~ The reference level (Intercept) is represented by 'Farmland' for Habitat and 'Common Nightingale' for Species. Random effect variance: 0.8 ± 0.9.

Table S1b. Ability to hear playback calls in farmland and woodland in relation to distance (GEE model).

Variable	Estimate	Standard error	w value	P value
Intercept	1.297	0.272	22.679	1.9e-06
SReal distance	-1.613	0.153	110.959	< 2e-16
Habitat (Woodland)	1.466	0.316	21.463	3.6e-06
Species (Little Owl)	1.896	0.416	20.730	5.3e-06
Species (Long-eared Owl)	-0.784	0.296	7.032	0.008
Species (Tawny Owl)	1.576	0.410	14.763	0.0001
Species (Water Rail)	-0.053	0.261	0.040	0.841

Model outcome showing fixed effects. ~~The model was fitted with the command geeglm (geepack package) with the formula: *Regis heard ~ SReal distance + Habitat + Species*, where *Regis heard* stands for surveyor ability to have heard or not playback calls and *Real distance* was scaled (*S*). The model accounted for the potential non-independence of observations specifying in the formula: *id = Group, waves = Time order, corstr = "unstructured"*. *Group* identifies species broadcasts within a playback repetition (each group combined point identity and repetition number); *Time order* identifies the order of observations (broadcast calls) and *corstr = "unstructured"* specifies the correlation structure.~~ The reference level (Intercept) is represented by 'Farmland' for Habitat and 'Common Nightingale' for Species. Model alpha parameter: 1.2 ± 0.1.

Table S1c. Ability to estimate playback distances correctly in farmland and woodland in relation to distance.

Variable	Estimate	Standard error	Z value	P value
Intercept	-2.516	0.482	-5.220	1.7e-07
SReal distance	-1.393	0.163	-8.560	< 2e-16
Habitat (Woodland)	1.888	0.585	3.230	0.001
Species (Little Owl)	-0.290	0.309	-0.940	0.348
Species (Long-eared Owl)	-1.593	0.355	-4.490	7.0e-06
Species (Tawny Owl)	-0.441	0.312	-1.410	0.157
Species (Water Rail)	-0.241	0.308	-0.780	0.435

Model outcome showing fixed effects. ~~Model formula: *Estimate correct ~ SReal distance + Habitat + Species + (1|Point)*, where *Estimate correct* stands for surveyor ability to have estimated playback distances correctly or not and *Real distance* was scaled (*S*).~~ The reference level (Intercept) is represented by 'Farmland' for Habitat and 'Common Nightingale' for Species. Random effect variance: 1.3 ± 1.2.

Table S1d. Ability to hear playback calls in woodland in relation to distance and season.

Variable	Estimate	Standard error	Z value	P value
Intercept	0.916	0.419	2.190	0.029
SReal distance	-1.419	0.185	-7.670	1.8e-14
Season (Winter)	1.601	0.299	5.350	8.8e-08
Species (Little Owl)	2.335	0.452	5.160	2.5e-07
Species (Long-eared Owl)	-0.105	0.323	-0.320	0.746
Species (Tawny Owl)	2.335	0.452	5.160	2.5e-07
Species (Water Rail)	0.107	0.327	0.330	0.742
SReal distance:Season (Winter)	-0.161	0.322	-0.500	0.617

Model outcome showing fixed effects. ~~Model formula: *Regis heard ~ SReal distance*Season + Species + (1|Point)*. The expression in the formula *SReal distance*Season* and in the output SReal distance:Season indicates the interaction between distance and season and *Real distance* was scaled (*S*).~~ The reference level (Intercept) is represented by 'Summer' for Season and 'Common Nightingale' for Species. Random effect variance: 1.1 ± 1.

Table S1e. Ability to hear playback calls in woodland in relation to distance and season (without outliers).

Variable	Estimate	Standard error	Z value	P value
Intercept	0.975	0.543	1.790	0.073
SReal distance	-1.646	0.208	-7.930	2.2e-15
Season (Winter)	1.953	0.339	5.740	9.2e-09
Species (Little Owl)	2.563	0.479	5.350	8.7e-08
Species (Long-eared Owl)	-0.003	0.343	-0.010	0.994
Species (Tawny Owl)	2.715	0.494	5.490	4.0e-08
Species (Water Rail)	0.179	0.347	0.520	0.605
SReal distance:Season (Winter)	-0.139	0.369	-0.380	0.707

Model outcome obtained removing the outliers. ~~Model formula: *Regis heard ~ SReal distance*Season + Species + (1|Point)*. The expression in the formula *SReal distance*Season* and in the output SReal distance:Season indicates the interaction between distance and season and *Real distance* was scaled (*S*).~~ The reference level (Intercept) is represented by 'Summer' for Season and 'Common Nightingale' for Species. Random effect variance: 2.2 ± 1.5.

Table S1f. Ability to hear playback calls in woodland in relation to distance and season (GEE model).

Variable	Estimate	Standard error	w value	P value
Intercept	0.760	0.255	8.870	0.003
SReal distance	-1.038	0.237	19.190	1.2e-05
Season (Winter)	1.364	0.320	18.180	2.0e-05
Species (Little Owl)	1.987	0.391	25.860	3.7e-07
Species (Long-eared Owl)	-0.091	0.255	0.130	0.722
Species (Tawny Owl)	1.981	0.395	25.200	5.2e-07
Species (Water Rail)	0.083	0.226	0.130	0.715
SReal distance:Season (Winter)	-0.448	0.302	2.200	0.138

Model outcome obtained removing the outliers. ~~The model was fitted with the command geeglm (geepack package) with the formula: *Regis heard ~SReal distance*Season + Species*. The expression in the formula *SReal distance* Season* and in the output SReal distance:Season indicates the interaction between distance and season and *Real distance* was scaled (*S*). The model accounted for the potential non-independence of observations specifying in the formula: *id = Group, waves = Time order, corstr = "unstructured"*. *Group* identifies species broadcasts within a playback repetition (each group combined point identity and repetition number); *Time order* identifies the order of observations (broadcast calls) and *corstr = "unstructured"* specifies the correlation structure.~~ The reference level (Intercept)is represented by 'Summer' for Season and 'Common Nightingale' for Species. Model alpha parameter: 0.3 ± 0.2.

Table S1g. Ability to estimate playback distances correctly in woodland in relation to distance and season.

Variable	Estimate	Standard error	Z value	P value
Intercept	-0.239	0.269	-0.890	0.374
SReal distance	-0.756	0.123	-6.140	8.4e-10
Season (Winter)	-0.619	0.188	-3.300	0.0009
Species (Little Owl)	-0.032	0.253	-0.130	0.899
Species (Long-eared Owl)	-0.676	0.262	-2.580	0.009
Species (Tawny Owl)	-0.162	0.254	-0.640	0.525
Species (Water Rail)	-0.162	0.254	-0.640	0.525
SReal distance:Season (Winter)	-0.582	0.227	-2.560	0.010

Model outcome showing fixed effects. ~~Model formula: *Estimate correct ~ SReal distance *Season + Species + (1|Point)*. The expression in the formula *SReal distance*Season* and in the output SReal distance:Season indicates the interaction between distance and season and *Real distance* was scaled (*S*).~~ The reference level (Intercept)is represented by 'Summer' for Season and 'Common Nightingale' for Species. Random effect variance: 0.3 ± 0.6.

Table S1h. Ability to estimate playback distances correctly in woodland in relation to distance and season (without outliers).

Variable	Estimate	Standard error	Z value	P value
Intercept	-0.344	0.292	-1.180	0.238
SReal distance	-1.010	0.141	-7.150	8.5e-13
Season (Winter)	-0.875	0.223	-3.920	8.9e-05
Species (Little Owl)	-0.036	0.269	-0.130	0.893
Species (Long-eared Owl)	-0.923	0.285	-3.240	0.001
Species (Tawny Owl)	-0.183	0.270	-0.680	0.499
Species (Water Rail)	-0.216	0.271	-0.800	0.426
SReal distance:Season (Winter)	-0.888	0.281	-3.160	0.0016

Model outcome obtained removing the outliers. ~~Model formula: *Estimate correct ~SReal distance*Season + Species + (1|Point)*. The expression in the formula *SReal distance*Season* and in the output SReal distance:Season indicates the interaction between distance and season and *Real distance* was scaled (*S*).~~ The reference level (Intercept) is represented by 'Summer' for Season and 'Common Nightingale' for Species. Random effect variance: 0.4 ± 0.6.

Tables S2-S3: errors in distance estimation

Table S2. Errors in distance estimation made by the surveyor across surveys. The total number of broadcast calls is 400 in each survey.

Distance class (m)	Survey	Number of detected broadcasts	Number of wrong estimates	Percentage of wrong estimates (%)	Number of OE	Percentage of OE (%)	Number of UE	Percentage of UE(%)
0-100			0	0	0	0	0	0
100-200			36	14.5	36	14.5	0	0
200-300			61	24.6	61	24.6	0	0
300-400	First	288	67	27.0	67	27.0	0	0
400-500			46	18.6	46	18.6	0	0
>500			38	15.3	38	15.3	0	0
Total			248	100	248	100	0	0
0-100			0	0	0	0	0	0
100-200			46	21.4	46	21.4	0	0
200-300	Second	366	107	49.8	107	49.8	0	0
300-400			48	22.3	48	22.3	0	0
400-500			10	4.7	10	4.7	0	0
>500			4	1.9	4	1.9	0	0
Total			215	100	215	100	0	0
0-100			33	23.7	0	0	33	66.0
100-200			44	31.7	27	30.3	17	34.0
200-300	Third	289	39	28.1	39	43.8	0	0
300-400			23	16.6	23	25.8	0	0
400-500			0	0	0	0	0	0
>500			0	0	0	0	0	0
Total			139	100	89	100	50	100

Number and percentages of wrong distance estimates (for the calls that have been detected) per distance class made by the surveyor. Overestimates (OE) consist in estimates made in a class further than the correct one (i.e. further from the surveyor position), while underestimates (UE) consist in estimates made in a class prior than the correct one (i.e. closer to the surveyor position). Distances estimated wrongly declined across surveys, with underestimates placed only in the first two distance classes of the last survey. The first column indicates all the possible distance classes planned for the experiment, in which the surveyor could assign playback calls. Unlike **Table 1**, which provides real distance classes (i.e. those where the broadcaster actually stationed at), here there are also ‘400 - 500 m’ and ‘> 500 m’ because the surveyor, being unaware of the broadcaster’s position, could assign calls in these two classes too.

Table S3. Errors in distance estimation made by the surveyor across the surveys in relation to species. The total number of broadcast calls is 400 in each survey.

Species	**Survey**	**Number of detected broadcasts**	**Number of wrong estimates**	**Percentage of wrong estimates (%)**	**Number of OE**	**Percentage of OE (%)**	**Number of UE**	**Percentage of UE (%)**
Common Nightingale			44	17.7	44	17.7	0	0
Water Rail			44	17.7	44	17.7	0	0
Little Owl	First	288	62	25.0	62	25.0	0	0
Long-eared Owl			39	15.7	39	15.7	0	0
Tawny Owl			59	23.8	59	23.8	0	0
Total			248	100	248	100	0	0
Common Nightingale			33	15.4	33	15.4	0	0
Water Rail			37	17.2	37	17.2	0	0
Little Owl	Second	366	45	20.9	45	20.9	0	0
Long-eared Owl			51	23.7	51	23.7	0	0
Tawny Owl			49	22.8	49	22.8	0	0
Total			215	100	215	100	0	0
Common Nightingale			19	13.7	10	11.2	9	18.0
Water Rail			23	16.5	13	14.6	10	20.0
Little Owl	Third	289	39	28.1	28	31.5	11	22.0
Long-eared Owl			19	13.7	10	11.2	9	18.0
Tawny Owl			39	28.1	28	31.5	11	22.0
Total			139	100	89	100	50	100

Number and percentages of wrong distance estimates (for the calls that have been detected) per distance class made by the surveyor. The table reflects **Table S2**, but here over- (OE) and underestimates (UE) are referred to species. Generally, most distances estimated wrongly are associated with owls.

Tables

Table 1. Summary of the values obtained during the field experiment.

Distance class (m)	Number of broadcast calls	Percentage of broadcast calls (%)	Number of correct distance estimates	Percentage of correct distance estimates (%)	Number of calls detected	Percentage of calls detected (%)
0-100	315	26.3	148	46.9	312	99.1
100-200	615	51.3	148	24.1	490	79.7
200-300	240	20.0	36	25.7	132	55.0
300-400	30	2.5	5	16.7	9	30.0
Total	1200	100	337	28.1	943	78.6

Number and percentage of broadcast calls, correct distance estimates and calls detected according to distance classes.

Legends to figures

Figure 1: Binomial GLMM showing the predicted probabilities of hearing playback calls in farmland (n = 400) and woodland (n = 400) in relation to distance.

Figure 2: Binomial GLMM showing the predicted probabilities of estimating distances correctly in farmland (n = 400) and woodland (n = 400) in relation to distance.

Figure 3: Binomial GLMM showing the predicted probabilities of hearing playback calls in woodland in relation to distance and season (n = 400 in winter and n = 400 in summer).

Figure 4: Binomial GLMM showing the predicted probabilities of estimating distances correctly in woodland in relation to distance and season (n = 400 in winter and n = 400 in summer).

Figure 5: Pictures taken in woodland at the same point in winter and summer to show the difference in terms of vegetation structure, which can act as a natural "acoustic barrier".

Figures

Figure 1

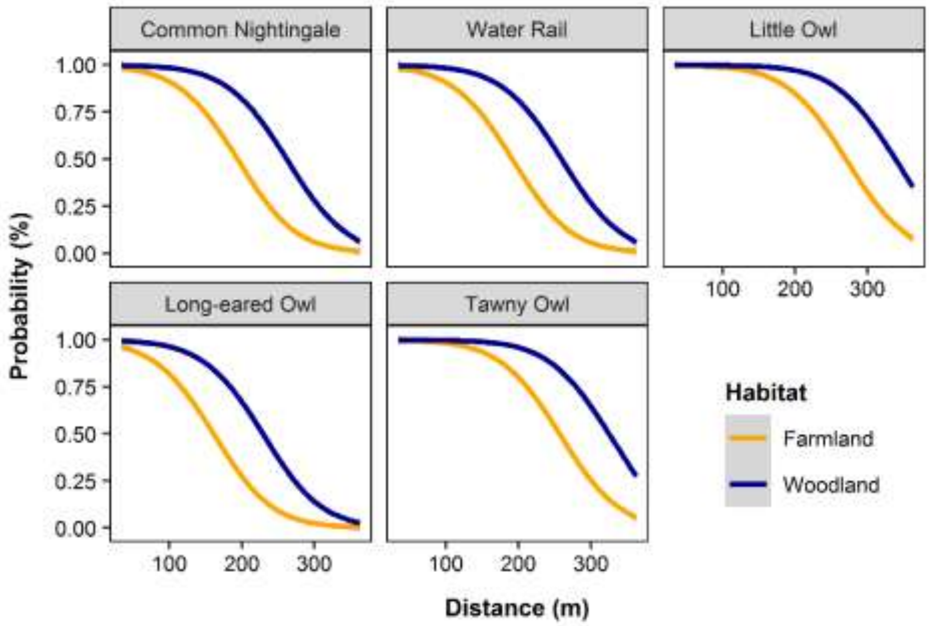

Figure 2

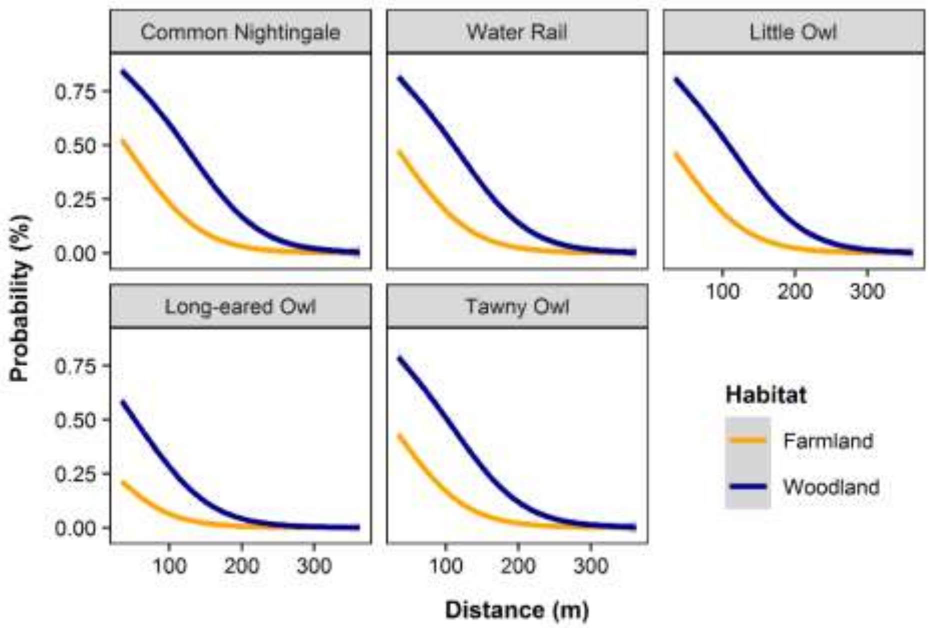

Figure 3

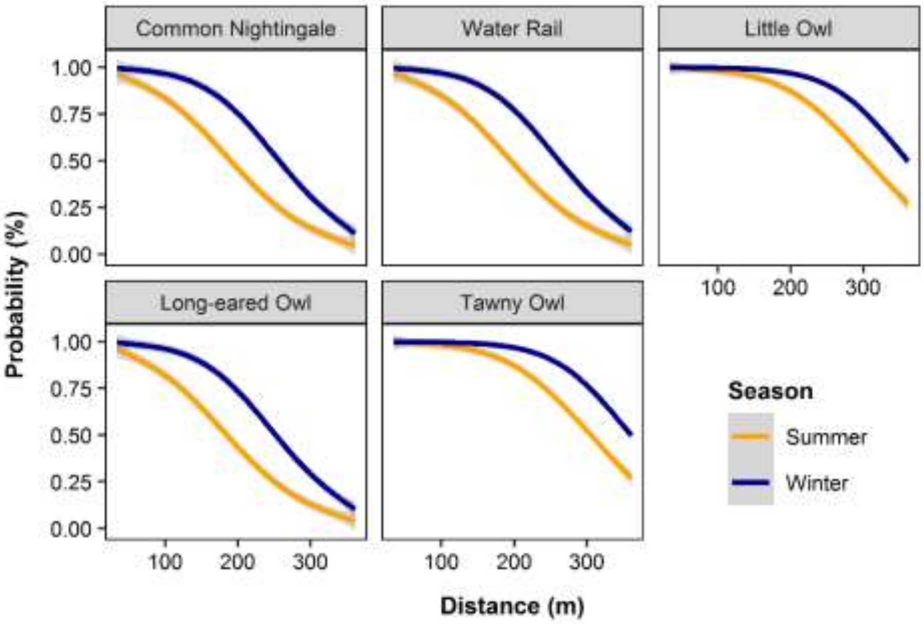

Figure 4

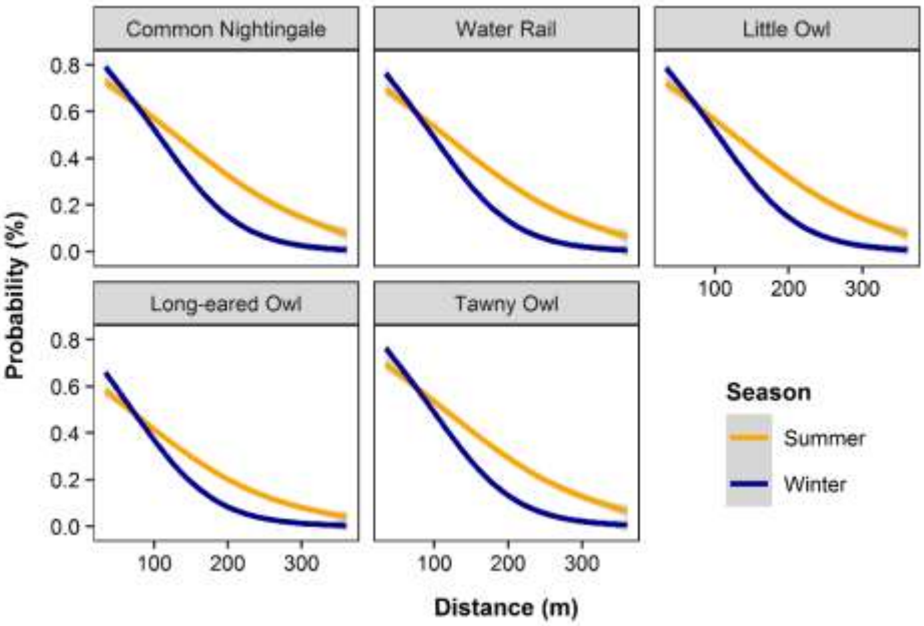

Figure 5