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

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

16

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24 **Short title:** Playback field evaluation

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

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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 aquaticus*) 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.

84 Introduction

85

86 Playback is commonly used to survey birds as it represents an efficient method to census elusive species ~~thus~~
87 by improving their detection probability (Hardy & Morrison 2000, Navarro *et al.* 2005, Stermin *et al.* 2017).
88 This technique consists of broadcasting generally conspecific recorded calls in order to elicit their vocal reply
89 (Johnson *et al.* 1981, Worthington-Hill & Conway 2017). This is particularly useful for those species that
90 exhibit territorial behaviour because they will be more inclined to respond in order to defend their territories
91 (Haug & Didiuk 1993, Pilla *et al.* 2018). Relying only on spontaneous vocalisations can be insufficient, because
92 they may limit census performance ~~may be insufficient, thus limiting census performance~~ (Crowe &
93 Longshore 2013). It is known that factors such as habitat, seasonality, time of day and weather can influence
94 response rates during playback surveys (Hardy & Morrison 2000, Currie *et al.* 2002, Polak 2005, Braga *et al.*
95 2009, Johnson *et al.* 2009). In addition, more technical parameters such as sound amplitude level and
96 surveyor detection ability or experience (Crowe & Longshore 2013, Zuberogitia *et al.* 2020) are also
97 fundamental as they enable a detectability radius to be defined, which is a threshold distance expressing at
98 what scale bird distributions can be better estimated, i.e. a distance around playback points within which a
99 surveyor has higher probabilities to detect birds. Usually, only responses detected at a distance within the
100 radius are included in the analysis, since it provides some level of security, so that results include most
101 individuals actually occupying a given area ~~which is the maximum distance around playback points that~~
102 ~~allows surveyors to hear and detect birds. Responses from an estimated distance greater than the selected~~
103 ~~radius are not considered reliable and are typically excluded from the analysis~~ (Centili 2001, Johnson *et al.*
104 2009, Bolboacă *et al.* 2015). Therefore, the detectability radius has a key role in minimizing biases. During
105 aural surveys, distance estimation is clearly more difficult than for visual detections and making errors in
106 estimation can consequently bias the results (Marques 2004).

107 Field evaluations prior to actual playback surveys therefore represent a useful step to adjust the method
108 by setting a fixed distance (and so a radius) calibrated on the surveyor's detection capability in the field
109 (Esclarski & Cintra 2014), where radial distance is a function of the surveyor's ability to estimate bird-surveyor

110 distance and to hear broadcast calls. Experimental trials of this kind can help researchers to conduct playback
111 surveys as accurately as possible. From this perspective, we carried out a field experiment aimed to evaluate
112 the effect of distance on detectability in different habitats within an agricultural landscape, by addressing the
113 following questions:

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

116
117 (ii) Does the effect of distance in woodland have the same effect on detection probability in summer
118 and winter?

119

120 In this way, we aimed to understand at what scale nocturnal species detection and distribution can be
121 estimated in this landscape. As target species, we used territorial playback songs/calls of Common
122 Nightingale *Luscinia megarhynchos*, Little Owl *Athene noctua*, Tawny Owl *Strix aluco*, Long-eared Owl *Asio*
123 *otus* and Water Rail *Rallus acquaticus*. Within our study region, these species form a common bird community
124 with similar elusive habits. These birds are territorial, hard to see, and more active at night. For these reasons,
125 they are frequently censused through playback, especially from dusk and at night (Zuberogoitia & Campos
126 1998, Schmidt *et al.* 2006, Brambilla & Jenkins 2009, Seoane & Galván 2010, Stermin *et al.* 2017). Through
127 our experiment, we attempted to provide a valid insight into the playback method in surveying our target
128 species effectively.

129

130

131 **Methods**

132 **Study area**

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

135 'Parco del Po Vercellese-Alessandrino', in the southern part of Vercelli Province. The first site consisted of a
136 typical intensive agricultural landscape close to a wetland area (named 'Riserva Naturale Speciale e Zona di
137 Salvaguardia della Palude di San Genuario', 8°10'54"E, 45°13'7"N) dominated by rice fields, the most
138 important cultivation of the area. The second site was an oak-hornbeam (*Quercus* and *Populus Carpinus*
139 species) woodland area (named 'Parco Naturale del Bosco delle Sorti della Partecipanza', 8°16'1"E,
140 45°13'50"N). Both sites are SCIs (Sites of Community Importance) and ZSPs (Zones of Special Protection under
141 the Birds Directive).

142

143 **Field survey protocol**

144

145 We designed the playback field experiment as follows: in each habitat we established one transect with ten
146 points, spaced 200 m apart, and each point was visited eight times (i.e. eight repetitions). At each repetition,
147 one researcher (the 'broadcaster') moved to a random location around one single surveyor (the 'observer')
148 and broadcast the whole call sequence (noting the time of broadcast) of all five species. The surveyor stayed
149 fixed at each point and (i) noted the time and species when a call was detected and (ii) estimated playback
150 distances (assigning calls to distance classes of between 0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-
151 500 m and >500 m). At each repetition, the surveyor did not know the location of the broadcaster. We used
152 a handheld GPS (Garmin eTrex 10) to identify survey points and to note the location of each playback made
153 by the broadcaster. We conducted one survey in farmland and one in woodland in winter (between the end
154 of February and the beginning of March 2020); then we repeated a third survey only in woodland in summer
155 (mid-July 2020) to test for a seasonal effect in this habitat. We performed all surveys in good weather
156 conditions (i.e. not on rainy or windy days). Although the target species were nocturnal (Long-eared Owl,
157 Tawny Owl), crepuscular, or more vocally active at night (Water Rail, Little Owl, Nightingale), we carried out
158 the surveys in daylight, partly due to access restrictions, but also to minimise the potential confounding
159 effects of real (rather than recorded broadcast) vocalizations.

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

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

179

180 **Data analysis**

181

182 We used Garmin BaseCamp software to download location data from the GPS and to calculate real distances
183 between the surveyor and broadcaster. To evaluate the effect of distance on detection probability, we used
184 a mixed modelling approach, fitting binomial generalized linear mixed models (GLMM) to explain the
185 probability of hearing playback calls (binomial response: 1 = calls heard; 0 = calls not heard) and the

186 probability of estimating distances of those calls that were detected correctly (binomial response: 1 = calls
187 estimated in the correct distance class; 0 = calls not estimated in the correct distance class). Survey point
188 identity was specified as a random effect in order to account for repeated observations from the same point,
189 and real distances, habitat and species were specified as fixed effects. To test for a seasonal effect in
190 woodland, we used the same approach and included season (winter or summer) and the interaction term
191 between Real distance and season. Before modelling, the 'Real distance' variable was scaled. Models were
192 validated using the Hosmer-Lemeshow goodness of fit test (Hosmer & Lemeshow 2000), where a significant
193 test result (as measured by the chi-squared statistic) indicates poor model fit. When this occurred, we used
194 Cook's distance (Cook 1979) to identify and remove potential outliers.

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

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

208

209

210 **Results**

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

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220 **Effect of distance on detectability in both habitats in winter**

221

222 The ability to hear playback calls across all species declined significantly with distance (slope = -1.64 ± 0.17 , z
223 = -9.69 , $p < 0.001$; **Table S1a**, Appendix). Predicted probabilities of hearing calls were often high at 200 m,
224 especially in woodland, and the easiest species to hear was Little Owl (estimated probability = 0.97), followed
225 by Tawny Owl (0.96), Common Nightingale (0.82), Water Rail (0.81) and Long-eared Owl (0.67; **Figure 1**). At
226 a distance of 300 m, probabilities dropped, particularly for Long-eared Owl, Water Rail and Common
227 Nightingale (respectively 0.14, 0.26 and 0.28 in woodland). Detection probabilities were always significantly
228 higher in woodland than farmland ($p < 0.001$). The Hosmer-Lemeshow test showed a good model fit ($\chi^2 =$
229 8.09 , $df = 8$, $p > 0.05$). The GEE model supported the GLMM in that hearing playback calls declined with
230 distance very similarly (slope = -1.61 ± 0.15 , $w = 110.96$, $p < 0.001$; **Table S1b**, Appendix). The lack of any
231 qualitative difference between the GLMM and GEE results thus suggests that potential temporal
232 autocorrelation between the calls in a given sequence did not affect the conclusions regarding the estimates
233 of probability of hearing calls in relation to distance.

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

237 200 m and <3% at 300 m (**Figure 2**). In woodland at 200 m, the best estimates were associated with Common
238 Nightingale (0.17) and the lowest with Long-eared Owl (0.04). Probabilities were significantly higher in
239 woodland than farmland ($p < 0.01$). The Hosmer-Lemeshow test showed a good model fit ($\chi^2 = 9.40$, $df = 8$, p
240 > 0.05).

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

246

247

248 **Seasonal variation in woodland**

249

250 The effect of distance on the ability to hear playback calls was significant (slope = -1.42 ± 0.19 , $z = -7.67$, $p <$
251 0.001 ; **Table S1d**, Appendix), but did not change between the second and third survey, i.e. there was no
252 difference in slope between winter and summer (parameter estimate = -0.16 ± 0.32 , $z = -0.5$, $p > 0.05$).
253 However, season was significant ($p < 0.001$) and predicted probabilities were higher in winter (**Figure 3**). Little
254 Owl and Tawny Owl were the easiest species to detect, and Long-eared Owl the hardest (respectively 0.97,
255 0.97 and 0.74 at 200 m in winter). At 200 m, probabilities were generally high, but at 300 m they were always
256 less than 52 % in summer and 72% in winter. The Hosmer-Lemeshow test did not show a good model fit (χ^2
257 = 26.0, $df = 8$, $p < 0.05$). We investigated this poor model fit by looking for possible outliers ~~i.e. the~~
258 ~~observations that mostly negatively influenced the model~~ ~~We used Cook's distance approach (Cook 1979)~~
259 and we dropped the observations ($n = 6$) which revealed the highest Cook's distance values. This was the
260 minimum number of observations that enabled an improvement in model fit ($\chi^2 = 11.0$, $df = 8$, $p > 0.05$). No
261 qualitative differences were found in the model results (**Table S1e**, Appendix).

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

265 Overall, playback distances were estimated increasingly erroneously in more distant zones (slope = -0.76
266 ± 0.12 , $z = -6.14$, $p < 0.001$; **Table S1g**, Appendix) and there was a significant seasonal variation (parameter
267 estimate = -0.58 ± 0.23 , $z = -2.56$, $p < 0.05$). Predicted probabilities were generally higher in summer than in
268 winter (**Figure 4**) and higher at 200 m than 300 m for all species. ~~Probabilities were quite high at 200 m for~~
269 ~~all species, but they dropped at 300 m.~~ Higher probabilities were associated with Little Owl and Common
270 Nightingale (both 0.32 at 200 m and 0.14 at 300 m in summer), while the Long-eared Owl remained the most
271 difficult species to estimate (0.20 at 200 m and 0.08 at 300 m in summer). The Hosmer-Lemeshow test did
272 not show a good model fit ($\chi^2 = 29.0$, $df = 8$, $p < 0.05$). So, as before, we dropped the minimum number of
273 observations ($n = 20$) with the highest Cook's distance values which enabled to improve the model fit ($\chi^2 =$
274 14.0 , $df = 8$, $p > 0.05$). No qualitative differences were found in the model results, except for an increase in
275 the significance of seasonal variation (parameter estimate = -0.89 ± 0.28 , $z = -3.16$, $p < 0.01$; **Table S1h**,
276 Appendix).

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

282

283

284 **Discussion**

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

287 ~~estimating their distances in the correct distance class.~~ Other studies have attempted to evaluate the
288 response distance of elusive birds and the distance from the surveyor (Proudfoot *et al.* 2002, Flesch & Steidl
289 2007, Bartolommei *et al.* 2012), because its measurement helps to improve detection and determine bird
290 densities. Monitoring nocturnal birds, Puglisi & Bartolommei (2012) estimated the distance of detected birds
291 from the surveyor, selecting four distance classes (<50, 50–100, 100–300 and >300 m). They always detected
292 Long-eared Owl at distances less than 100 m, whereas Little Owl and Tawny Owl were detected across all
293 classes. Such classes were considered by Bartolommei *et al.* (2012), who adopted a 300 m radius in their
294 methods to investigate the presence and distribution of Little Owl and Tawny Owl according to land-use
295 categories in an agricultural landscape of Central Italy. ~~These estimates reflect our own investigation into~~
296 ~~surveyor's estimation ability~~ Instead, unlike Bartolommei *et al.* (2012), ~~but~~ in our experiment we specifically
297 fitted models to evaluate separately the probability to detect calls and to estimate distances correctly in
298 relation to distance, testing also a seasonal effect.

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

311

312 **The effect of distance on surveyor detection capability**

313

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

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

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

339 varied significantly with season. This fact is likely due to an increase in our field experience. After the first
340 survey, we were able to better calibrate estimates and reduce errors, in particular in terms of overestimated
341 distances. For detected calls, distance estimate errors decreased by 8.3 % between the first and second
342 survey and by 19 % between the second and the third. Surveyor experience has already been demonstrated
343 to be a relevant factor affecting bird detection probabilities (Booms *et al.* 2010, Jiguet & Williamson 2010,
344 Johnston *et al.* 2018), including nocturnal species (Zuberogoitia *et al.* 2020). A radial distance of about 200
345 m, at which playback could be heard, has previously been adopted to census Tawny Owls (Appleby *et al.*
346 1999). In another case, a distance of 300 m was used for Tawny Owl and Little Owl (Bartolommei *et al.* 2012)
347 as it proved to be the best estimated distance for both species. Detection radius is not a constant value and
348 it varies across studies, because it changes according to target species, habitat and surveyor detection
349 capability (Centili 2001, Esclarski & Cintra 2014, Menq & Anjos 2015, Zuberogoitia *et al.* 2020). Therefore,
350 given these sources of variation, tests like ours should be made before playback surveys.

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

365 the case in our study. Indeed, errors occur even with wide distance classes and experienced observers
366 (Neubauer & Sikora 2020). We should stress that density estimation was not the purpose of our study.
367 Instead, our goal was an attempt to understand at what scale detection and distribution could be estimated
368 for our target species, which is likely a 200 m radius. At greater distances, detection probabilities became
369 very low.

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

376

377 **Field experiment timing and potential bias**

378

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

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

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

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555 **Appendix**

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

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561 **Table S1a.** Ability to hear playback calls in farmland and woodland in relation
 562 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

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

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582 **Table S1b.** Ability to hear playback calls in farmland and woodland in relation
 583 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

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

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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

600 Model outcome showing fixed effects. ~~Model formula: Estimate correct ~~~
 601 ~~SReal distance + Habitat + Species + (1|Point)~~, where ~~Estimate correct~~ stands
 602 ~~for surveyor ability to have estimated playback distances correctly or not and~~
 603 ~~Real distance was scaled (S)~~. The reference level (Intercept) is represented by
 604 'Farmland' for Habitat and 'Common Nightingale' for Species. Random effect variance: 1.3 ± 1.2.
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608 **Table S1d.** Ability to hear playback calls in woodland in relation to distance
 609 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

610 Model outcome showing fixed effects. ~~Model formula: Regis heard ~~~
 611 ~~SReal distance*Season + Species + (1|Point)~~. The expression in the formula ~~SReal~~
 612 ~~distance*Season~~ and in the output ~~SReal distance:Season~~ indicates the
 613 ~~interaction between distance and season and Real distance was scaled (S)~~.
 614 The reference level (Intercept) is represented by 'Summer' for Season and
 615 'Common Nightingale' for Species. Random effect variance: 1.1 ± 1.
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630 **Table S1e.** Ability to hear playback calls in woodland in relation to distance
631 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

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

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641 **Table S1f.** Ability to hear playback calls in woodland in relation to distance
642 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

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

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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

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

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672 **Table S1h.** Ability to estimate playback distances correctly in woodland in
 673 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

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

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692 **Tables S2-S3: errors in distance estimation**

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695 **Table S2.** Errors in distance estimation made by the surveyor across surveys. The total number of broadcast

696 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

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

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708 **Table S3.** Errors in distance estimation made by the surveyor across the surveys in relation to species. The
 709 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

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

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715 **Tables**

716 **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

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

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743 **Legends to figures**

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

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

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

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

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

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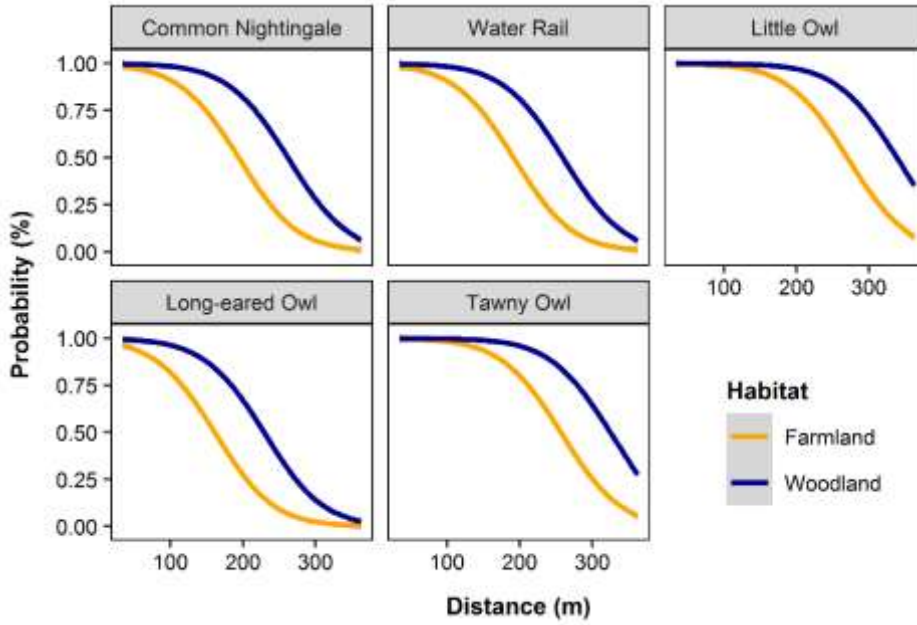
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776 **Figures**

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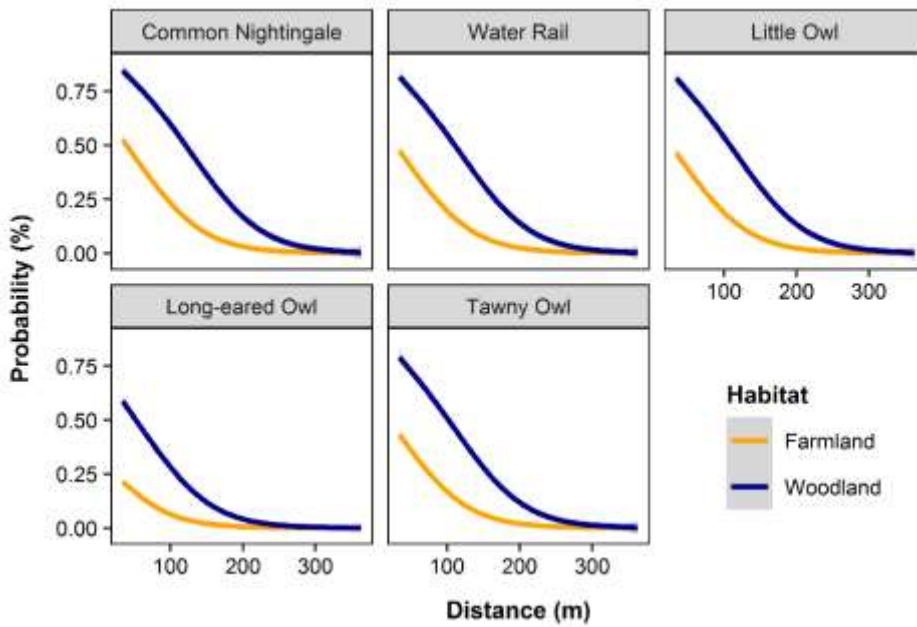
778 **Figure 1**



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781 **Figure 2**



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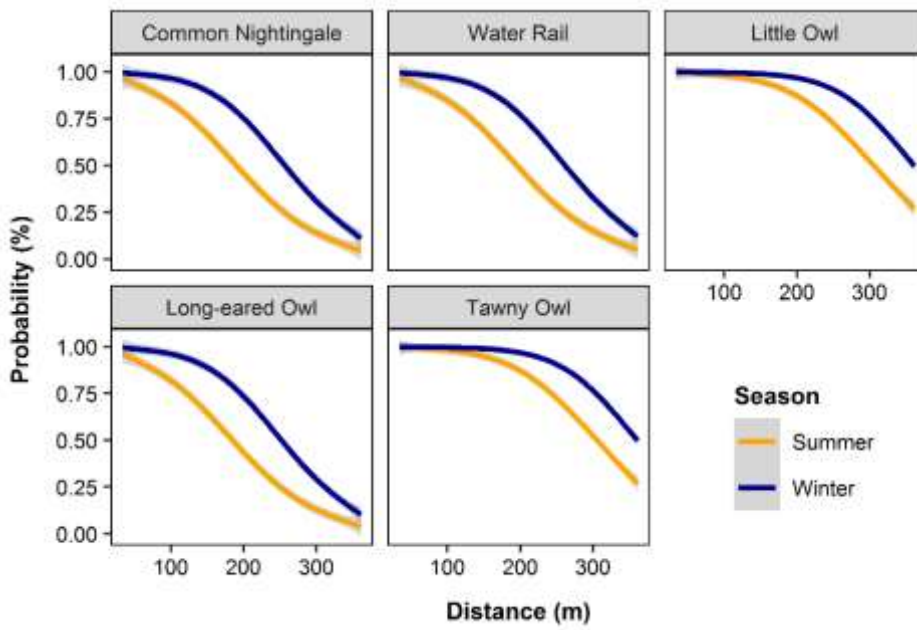
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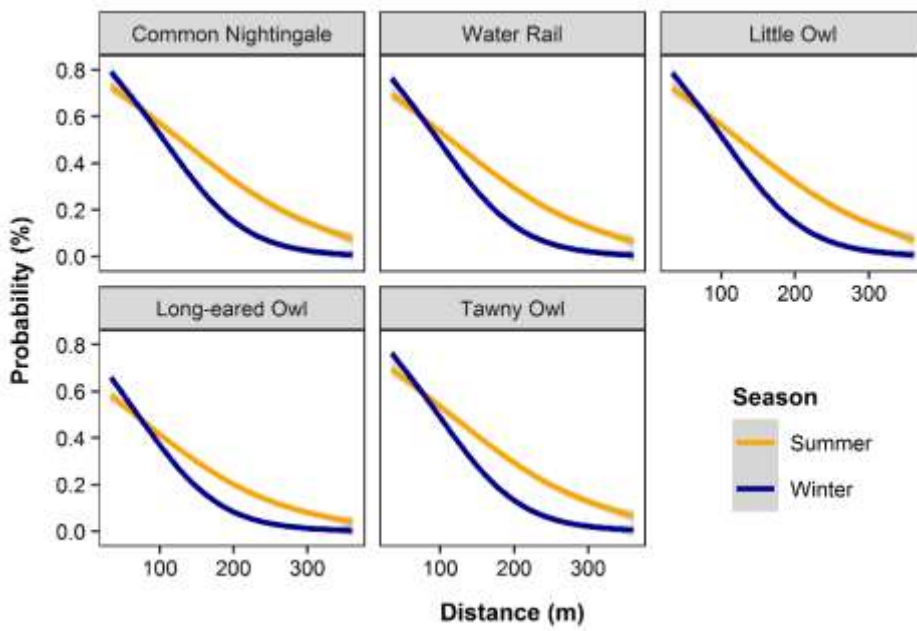
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787 **Figure 3**



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789 **Figure 4**



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791 **Figure 5**



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