

Are quartzite scree slopes used by birds to promote sound transmission in the Mediterranean forest?

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Abstract

Are quartzite scree slopes used by birds to promote sound transmission in the Mediterranean forest? Birds generate vocalisations (songs and calls) to communicate. Acoustic communication may be hindered by habitat features so birds can use several strategies to favour sound transmission. Sound transmission depends on the acoustic properties of their habitats. Scree slopes, also known as 'pedrizas', are frequent in the Mediterranean forests of south and central western Spain. As the acoustic properties of these rocky grounds might favour sound transmission, we propose that birds might actively use 'pedrizas' to increase sound transmission. We assessed the following prediction of the hypothesis: the number of vocalisations recorded should be higher near the 'pedrizas' than in forest areas far away from 'pedrizas'. Using portable recorders in the Mediterranean forest of Monfragüe National Park, we found that the number of recorded vocalisations was higher near the 'pedrizas'. As this result was not due to differences in species richness, we consider it supports the prediction of the hypothesis. This is new evidence that birds might use a natural element within their habitat to increase sound transmission.

Key words: Bird communication, Sound transmission, Rocky ground, Mediterranean forest, Natural soundscape

Resumen

¿Las aves utilizan las pendientes pedregosas (pedrizas) de cuarcita para fomentar la transmisión del sonido en los bosques mediterráneos? Las aves generan vocalizaciones (melodías y llamadas) para comunicarse. Como la comunicación acústica puede verse obstaculizada por ciertas características del hábitat, es posible que las aves se valgan de diferentes estrategias para favorecer la transmisión del sonido. La transmisión del sonido depende de las propiedades acústicas del hábitat. Las pedrizas son frecuentes en los bosques mediterráneos del oeste meridional y central de España. Las propiedades acústicas de este terreno pedregoso podrían favorecer la transmisión del sonido, de forma que la hipótesis que se formula es que las aves podrían utilizar las pedrizas para aumentar la transmisión del sonido. Se evaluó la siguiente predicción de la hipótesis: el número de vocalizaciones grabadas debería ser superior cerca de las pedrizas que en zonas forestales alejadas. En este estudio se utilizaron grabadoras portátiles en el bosque mediterráneo del Parque Nacional de Monfragüe, y el número de vocalizaciones grabadas fue superior cerca de las pedrizas. Este resultado no se debió a diferencias en la riqueza de especies, de manera que respalda la predicción de la hipótesis. Este es un nuevo indicio de que las aves podrían utilizar un elemento natural de su hábitat para aumentar la transmisión del sonido.

Palabras clave: Comunicación entre aves, Transmisión del sonido, Terreno pedregoso, Bosque mediterráneo, Paisaje sonoro natural

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Introduction

Vocalisations (songs and calls) are communicative signals used by birds to transmit information (Catchpole and Slater, 2008). Mate attraction, territorial defence and warning signals are functions of bird acoustic communication (Catchpole and Slater, 2008; Pärckert, 2018; Riebel et al., 2019). Despite the advantages in the evolutionary context of their functions, songs and calls might also imply costs regarding energy expenditure and detection by predators (Ward and Slater, 2005; Catchpole and Slater, 2008). It is expected that birds produce sounds when their advantages outweigh costs. Therefore, the number of discrete vocalisations they produce might depend on the presence of potential mates, competitors, or predators, as well as on physical properties such as the acoustic transmission through the habitats.

Information conveyed in bird vocalisations may be hindered by habitat features. Habitat complexity or noisy environments can modify signals and reduce their communicative function (Catchpole and Slater, 2008; Barker et al., 2009; Halfwerk et al., 2018). Birds might use several different strategies to avoid the loss of information, and they are able to match their songs and calls to the acoustic properties of the habitat (Hansen, 1979). For instance, Brumm (2004) found that nightingales (*Luscinia megarhynchos*) sing louder in noisy areas than in quieter places. Nicholls and Goldizen (2006) found that habitat type influences variation in the advertisement calls of the satin bowerbirds (*Ptilonorhynchus violaceus*), with transmission qualities of habitats being the main determinant of the effect.

One of the main problems for the transmission of a bird sound is that of attenuation (Wiley and Richards, 1978). The signal intensity decreases with distance from the source (Fang and Ling, 2005). However, other factors also produce attenuation and hence hinder the transmission of bird sounds (Bass, 1991). Habitat characteristics such as vegetation structure can influence the transmission of vocalisations (Proppe et al., 2010; Nasiri et al., 2015). Dense foliage, for instance, increases attenuation (Martens 1980; Blumenrath and Dabelsteen, 2004). In order to promote sound transmission, birds use different strategies, such as singing on perches high up in the vegetation (Catchpole and Slater, 2008; Barker et al., 2009). Some studies show that the benefits of long-distance transmission are more relevant to the birds than the benefits of advertising performance ability or the costs of song production (Benedict and Warning, 2017).

The Mediterranean forest includes an important community of animals and plants (Myers et al., 2000). Climax vegetation has been restricted to certain areas due to the strong pressure exerted by human activity over centuries. In central-western Spain, the best conserved Mediterranean forests are mainly found in quartzite mountainous areas where large steep stones are frequent. Within the forest there are some areas without vegetation forming scree slopes of quartzite origin, known in Spain as 'pedrizas' (see fig. 1). These fragmented rocks were produced during the Quaternary period by a gelifraction process (Pulido-Fernández et al.,

2013). A typical habitat in many mountain ranges of south and central western Spain is therefore a Mediterranean forest in which there are areas covered by 'pedrizas'.

The acoustic properties of these scree slopes differ from those in the surrounding forest. The presence of rocky surfaces predominates in 'pedrizas'. The acoustic impedance is high and can be considered mainly as acoustically reflective or hard surfaces in the terms indicated by the ISO standards (ISO 9613-2, 1996; ISO 1996-2, 2017). Therefore, when the sound waves reach such surfaces, a high percentage of the sound energy is reflected. In contrast, some elements present in the forest, such as bare earth and forest mass, contribute to sound attenuation (Bucur, 2006; Swearingen et al., 2013). The lower attenuation of bird sound on reflective surfaces has been shown in previous studies (Yip et al., 2017). In addition, 'pedrizas' are found in open spaces, thus being unaffected by other factors that affect the propagation and clarity of bird vocalisations, such as reverberation (Gogoleva, 2018).

Vegetation mass is expected to attenuate sounds and hinder bird communication in the Mediterranean forest. However, areas with 'pedrizas' could favour the transmission of information. Consequently, the effect of 'pedrizas' on sound transmission should be higher when birds' vocalisations are emitted on the 'pedrizas' and this effect should decrease as the distance of birds' vocalisations from 'pedrizas' increases. We therefore hypothesized that birds might use scree slopes to promote sound propagation and hence, to increase the transmission of their vocalisations. This hypothesis is not tested in this study. However, we assessed the following prediction of the hypothesis: if birds actively use scree slopes to promote sound transmission, the frequency of vocalisations recorded near the 'pedrizas' should be higher than that in forest areas far away from 'pedrizas'.

A high number of vocalisations recorded near the 'pedrizas' might be due to processes other than those related to sound transmission. 'Pedrizas' might ecologically influence bird distribution. In this case, a high number of vocalisations near 'pedrizas' would be due to the biased distribution of bird biodiversity. The relationship between the distance to 'pedrizas' and bird biodiversity is a necessary control to assess the prediction of the hypothesis. The lack of this relationship would support that a high number of vocalisations recorded near 'pedrizas' can be due to processes related to sound transmission.

The prediction of the hypothesis was assessed in the Mediterranean forest of Monfragüe National Park located in central-western Spain. As expected, we found that the frequency of vocalisation was higher the closer the sampling point was to 'pedrizas'. However, there was not a greater number of bird species near the 'pedrizas'.

Material and methods

The study was carried out in a highly conserved Mediterranean forest in Monfragüe National Park. This

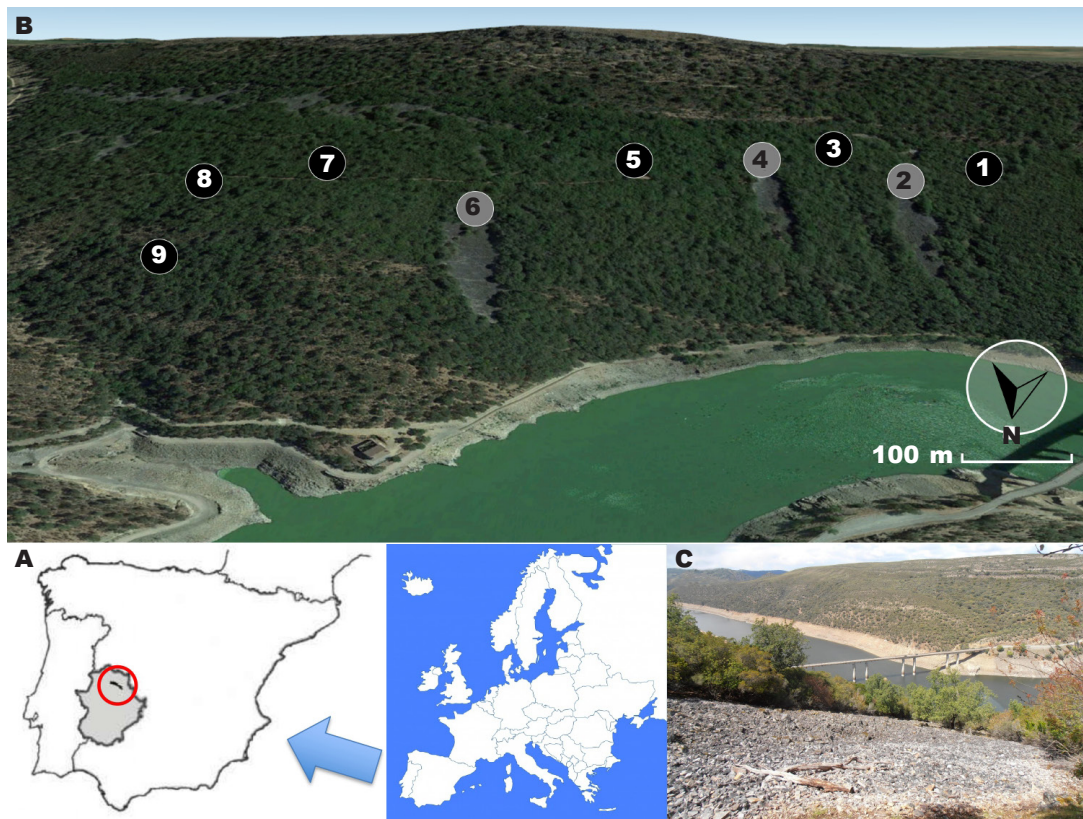


Fig. 1. A, location of Monfragüe National Park; B, study area in Monfragüe National Park: numbers indicate the location of sampling points, black points indicate the sampling points at a distance from the 'pedrizas', and grey points indicate the sampling points on the three 'pedrizas' included in this study; C, view of a quartzite scree slope or 'pedriza'.

Fig. 1. A, ubicación del Parque Nacional de Monfragüe; B, zona de estudio en el Parque Nacional de Monfragüe: los números indican la ubicación de los puntos de muestreo, los círculos negros indican los puntos de muestreo alejados de las pedrizas y los círculos grises, los puntos de muestreo situados en las tres pedrizas incluidas en este estudio; C, vista de una pedriza de cuarcita.

forest is composed of cork oaks (*Quercus suber*) and several scrub species such as strawberry tree (*Arbutus unedo*), laurustinus (*Viburnum tinus*), myrtle (*Mirtus communis*), false olive (*Phillyrea angustifolia*) and heaths (*Erica* spp.). 'Pedrizas' are frequent in this area.

To record bird sounds, a portable Zoom H6 recorder was used with Roland Binaural microphones. The recorder was located at nine points in Monfragüe at different distances to three 'pedrizas' (fig. 1). Sampling locations were in a forest patch with the same vegetation species composition and the same northern orientation. The sizes of the 'pedrizas' are 3,450.63 m² ('pedriza' of point 2), 3,342.04 m² ('pedriza' of point 4) and 5,886.85 m² ('pedrizas' of point 6).

Recordings were made on February 28th, 2020. Bird vocalizations were recorded for 5 minutes at each sampling point. The first recording was made at 11:30 a.m. and the remaining recordings were conducted consecutively. The last recording ended

at 13:00 p.m. During recordings, the temperature was 15°C, with a mix of sun and clouds, and wind speed of 5 km/h.

All the vocalisations of the different bird species were identified in the recordings. Recordings were analysed and managed using the free software Sonic Visualiser (www.sonicvisualiser.org/) and Audacity (www.audacityteam.org/). Species were mainly identified aurally based on the the authors' experience, although the visual inspection of spectrograms helped in the process. The Birdnet web page was consulted in case of doubt (<https://birdnet.cornell.edu/api/>). A small proportion of vocalisations could not be identified as belonging to a specific species (see results) and were removed from subsequent analyses.

From each recording, we counted the number of recorded vocalisations produced by each bird species. In addition to the number of vocalisations, the other important variable in our study was the distance of each vocalisation to the 'pedrizas'. The

Table 1. Vocalisations from each bird species and across all species. The table shows the number and rate of recorded vocalisations, and the mean and standard error of the distance of the vocalisations to the 'pedrizas'. It also shows the *p* values of the one-sample T test for the difference between the mean distance of vocalisations to 'pedrizas' and the mean distance of all sampling points to the 'pedrizas' (0.298 km): NV, number of vocalisations; V/m, vocalisations per minute; MD, mean distance; SE, SE distance. (Standard error, SE, of distance equals 0 when all vocalisations were recorded at the same sampling point, so there was no variance in distance to the 'pedrizas'; ND if data are insufficient to obtain the parameter or to conduct the analysis; ND in SE distance was obtained when there was only one vocalisation; ND in *p* values was obtained when there was no SE of the distance to 'pedrizas' of vocalisations.)

*Tabla 1. Vocalizaciones de cada especie de ave y de todas las especies. En la tabla se muestran el número y la tasa de vocalizaciones grabadas, así como la media y el error estándar de la distancia entre el lugar de las vocalizaciones y las pedrizas. También se muestran los valores de *p* de la prueba de T de una única muestra para la diferencia entre la distancia media desde el lugar de las vocalizaciones hasta las pedrizas y la distancia media desde todos los puntos de muestreo hasta las pedrizas (0,298 km): NV, número de vocalizaciones; V/m vocalizaciones por minuto; MD, distancia media; SE, error estándar de la distancia. (El error estándar de la distancia es 0 cuando todas las vocalizaciones fueron grabadas en el mismo punto de muestreo, de forma que no hubo varianza en la distancia a las pedrizas; ND si no hay datos suficientes para obtener el parámetro ni para realizar el análisis; ND en el error estándar se obtuvo cuando solo hubo una vocalización; ND en los valores de *p* se obtuvo cuando no hubo error estándar de la distancia entre el lugar de las vocalizaciones y las pedrizas).*

Species	NV	V/m	MD	SE	<i>p</i>
<i>Fringilla coelebs</i>	470	10.444	0.213	0.002	< 0.001
<i>Certhia brachydactyla</i>	194	4.311	0.382	0.009	< 0.001
<i>Cyanistes caeruleus</i>	188	4.178	0.218	0.007	< 0.001
<i>Aegithalos caudatus</i>	130	2.889	0.311	0.012	0.262
<i>Phylloscopus collybita</i>	70	1.556	0.243	0	ND
<i>Garrulus glandarius</i>	43	0.956	0.204	0	ND
<i>Sitta europaea</i>	40	0.889	0.497	0	ND
<i>Sylvia cantillans</i>	22	0.489	0.161	0	ND
<i>Parus major</i>	18	0.400	0.249	0.015	0.005
<i>Sylvia atricapilla</i>	17	0.378	0.253	0.034	0.209
<i>Lullula arborea</i>	16	0.356	0.396	0	ND
<i>Periparus ater</i>	14	0.311	0.261	0.005	< 0.001
<i>Erithacus rubecula</i>	12	0.267	0.327	0.030	0.352
<i>Turdus merula</i>	8	0.178	0.283	0.044	0.760
<i>Carduelis spinus</i>	5	0.111	0.495	0	ND
<i>Serinus serinus</i>	3	0.067	0.495	0	ND
<i>Carduelis cannabina</i>	3	0.067	0.352	0.072	0.530
<i>Carduelis carduelis</i>	2	0.044	0.243	0	ND
<i>Sylvia melanocephala</i>	1	0.022	0.243	ND	ND
<i>Chloris chloris</i>	1	0.022	0.204	ND	ND
Across all species	1,257	27.933	0.267	0.003	< 0.001

distance of transmission of a vocalisation to the 'pedrizas' was quantified by averaging the distances from the sampling point where the vocalisation was recorded to the centroids of the three 'pedrizas'.

For each bird species, we recorded the number of vocalisations and the distance to 'pedrizas' for each vocalisation. We assessed the difference between the distance to the 'pedrizas' of the vocalisations and the

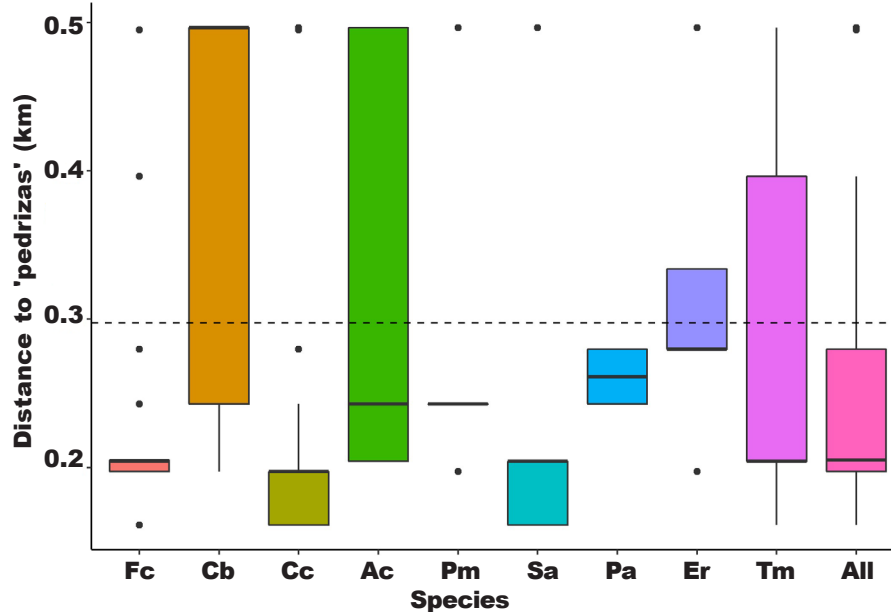


Fig. 2. Distance of vocalisations to 'pedrizas' recorded for each species and across all species. Boxplots were performed for the species with the highest number of vocalisations and with variance in the distance to 'pedrizas': Fc, *Fringilla coelebs*; Cb, *Certhia brachydactyla*; Cc, *Cyanistes caeruleus*; Ac, *Aegithalos caudatus*; Pm, *Parus major*; Sa, *Sylvia atricapilla*; Pa, *Periparus ater*; Er, *Erithacus rubecula*; Tm, *Turdus merula*; All, across all species). Distance to 'pedrizas' was quantified by averaging the distance of each vocalisation to the centroids of the three 'pedrizas'; horizontal dotted line, mean distance to 'pedrizas' of all sampling points.

Fig. 2. Distancia entre las pedrizas y el lugar de las vocalizaciones grabadas de cada especie y de todas las especies. Se generaron diagramas de caja para las especies con el mayor número de vocalizaciones y con varianza en la distancia a las pedrizas: Fc, *Fringilla coelebs*; Cb, *Certhia brachydactyla*; Cc, *Cyanistes caeruleus*; Ac, *Aegithalos caudatus*; Pm, *Parus major*; Sa, *Sylvia atricapilla*; Pa, *Periparus ater*; Er, *Erithacus rubecula*; Tm, *Turdus merula*; All, todas las especies). La distancia a las pedrizas se cuantificó calculando la distancia media del lugar de cada vocalización a los centroides de las tres pedrizas; línea horizontal discontinua, distancia media entre todos los puntos de muestreo y las pedrizas.

averaged distance to 'pedrizas' of all sampling points (0.298 km) using a sample T-test for each species and across species.

To assess the prediction of the hypothesis, we determined the relationship between the distance of the sampling points to the 'pedrizas' and the number of recorded vocalisations. A generalized linear mixed model (GLMM) fitted by maximum likelihood with Poisson distribution was used. For this model, the number of vocalisations was included as the explanatory variable, the distance to 'pedrizas' as the fixed factor, and sampling location as the random factor. In order to assess the effect of zero-inflation, the model was repeated after removing zero values.

Species richness in the recordings was used as an estimate of bird biodiversity. Species richness was a presence-absence binomial variable and was obtained after transforming the variable number of vocalisations. A zero value was assigned to species for which no vocalisations were recorded, and a value of 1 was assigned to species for which at least one

vocalisation was recorded. Therefore, to determine the relationship between the distance to 'pedrizas' and bird biodiversity, a GLMM fitted by maximum likelihood with binomial distribution was conducted with the presence-absence variable (species richness) as the explanatory variable, the distance to 'pedrizas' as the fixed factor, and sampling location as the random factor.

GLMMs were performed using the *lme4* package (Bates et al., 2015) in R software (R Core Team, 2019). Model residuals were checked for heteroscedasticity using residual plots. No signs of heteroscedasticity were found. Spatial analyses were conducted with QGIS (2021, www.QGIS.org).

Results

The averaged distance of each sampling point to the centroids of the 'pedrizas' was 0.28 km (point 1 in fig. 1), 0.197 km (point 2), 0.205 km (point 3),

Table 2. Relationship between the mean distance from the place of vocalisations to 'pedrizas' and the number of recorded vocalisations. Results from the GLMM with the number of vocalisations as the explanatory variable, the mean distance to 'pedrizas' as the fixed factor, and the sampling location as the random factor: SD, standard deviation.

Tabla 2. Relación entre la distancia media desde el lugar de las vocalizaciones hasta las pedrizas y el número de vocalizaciones grabadas. Resultados del modelo mixto lineal generalizado con el número de vocalizaciones como variable explicativa, la distancia media a las pedrizas como factor fijo y el lugar de muestreo como factor aleatorio: SD, desviación estándar.

Term	Estimate	SE	Variance	SD	z	p
GLMM using all data						
Fixed factors						
Intercept	3.083	0.715			4.313	< 0.001
Distance to 'pedrizas'	-4.911	2.241			-2.191	0.028
Random factor						
Sampling location			0.657	0.811		
GLMM after removing zero values						
Fixed factors						
Intercept	4.577	0.501	9.129	<0.001		
Distance to 'pedrizas'	-5.209	1.586			-3.285	0.001
Random factor						
Sampling location			0.317	0.563		

0.161 (point 4), 0.204 km (point 5), 0.243 km (point 6), 0.396 km (point 7), 0.497 km (point 8), and 0.495 km (point 9). The mean number of recorded vocalisations per minute was 27.93 and 7.3% of vocalisations were not identified. Unidentified vocalisations corresponded to short calls that were not determined by the authors or from the Birdnet web page. We identified 20 bird species in the recordings (table 1). Table 1 also shows the number of vocalisations from each species and across all species, and the mean distance of the recorded vocalisation to the centroids of 'pedrizas'. The mean distance to 'pedrizas' of vocalisations tended to be lower than the averaged distance to 'pedrizas' of all sampling points for several species (table 1, fig. 2). However, the mean distance to 'pedrizas' across all species was lower than the mean distance to 'pedrizas' of all sampling points (table 1, fig. 2).

The number of recorded vocalisations was negatively associated with the distance to the 'pedrizas' (table 2, fig. 3). This result was obtained when all data were used (table 2a, fig. 3) and after removing zero values (table 2b, fig. 3). Despite the general trend we found in our data, for one species (*Certhia brachydactyla*) we recorded high numbers of vocalisations far away from 'pedrizas' (table 1, fig. 2, and high number of vocalisations at high distance to 'pedrizas' in fig. 3).

Although the number of vocalisations was negatively associated with the distance to 'pedrizas', no relationship was found between the distance to 'pedrizas' and species richness (table 3). The lower distance to 'pedrizas' was not related to an increase in the number of bird species obtained in the recordings.

Discussion

In the Mediterranean forest of Monfragüe National Park, the number of vocalisations recorded near the 'pedrizas' was higher than in forest areas far away from 'pedrizas'. These results support the hypothesis that birds might actively use scree slopes to promote sound transmission.

In our study, the relationship between the distance to 'pedrizas' and bird biodiversity is a necessary control to assess the hypothesis. The distance to 'pedrizas' was not related to the estimated bird biodiversity. This result supports the notion that 'pedrizas' could not ecologically determine bird biodiversity. Factors related to resource availability or predation risk could not promote the presence of birds near 'pedrizas'. Therefore, the high number of vocalisations recorded near 'pedrizas' might be due to a better transmission of sound on scree slopes.

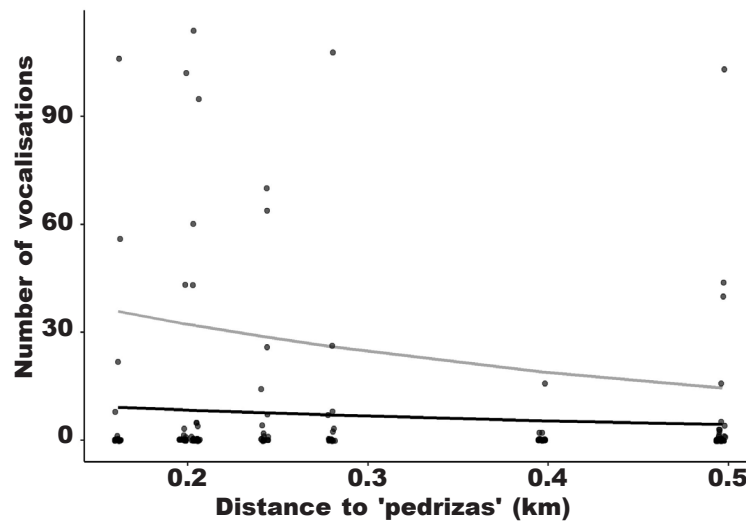


Fig. 3. Relationship between the distance to 'pedrizas' and the number of recorded vocalisations. Observed values are represented in jitter points to handling overplotting: black line, model prediction with all data (see table 2a); grey line, model prediction after removing zero values (see table 2b).

Fig. 3. Relación entre la distancia desde el lugar de las vocalizaciones hasta las pedrizas y el número de vocalizaciones grabadas. Los valores observados se representan mediante puntos con ajuste de posición (jitter) para evitar el solapamiento (overplotting): línea negra, predicción del modelo con todos los datos (véase la tabla 2a); línea gris, predicción del modelo tras eliminar los valores de cero (véase la tabla 2b).

Signal transmission is particularly conditioned by the propagation of sound in the environment (Winkler, 2001). Birds use different strategies to favour sound transmission: the wren (*Troglodytes troglodytes*) chooses higher song posts (Barker et al., 2009), male blue-black grassquits (*Volatinia jacarina*) leap vertically above the dense grass (Wilczynski et al., 1989) and male bluethroats (*Luscinia svecica*) sing in flight (Sorjonen and Merilä, 2000; Catchpole and Slater, 2008). Studies taking into account sound frequencies have found different behavioural strategies depending on ecological conditions (Boncoraglio and Saino, 2007; Ey and Fischer, 2009). The great tit produces sounds with a lower maximum frequency and frequency range in forests than in open woodland (Hunter and Krebs, 1979). The little greenbul (*Andropadus virens*) varies its minimum frequencies across a rainforest gradient in Africa (Slabbekoorn and Smith, 2002). The tinamou (*Eudromia elegans*) increases its vocal amplitude in response to the increase in background noise (Schuster et al., 2012). Additionally, woodpeckers hammer their bills rapidly against a resonating substrate to communicate, with hard surfaces (dead trees) being preferred by individuals (Miles et al., 2018). The selection of dead trees might help to increase sound intensity. The hypothesis of this study could be proposed as a strategy in which birds might actively use a natural element within their habitat to favour sound transmission.

We found a general trend based on all the species for which we recorded vocalisations in the

Mediterranean forest of Monfragüe National Park. Low sample sizes and the performing of multiple comparisons do not allow us to reach conclusions at species level. However, the hypothesis proposed in this work might be particularly important in some species. For instance, commonspecies such as the common chaffinch (*Fringilla coelebs*) or the blue tit (*Cyanistes caeruleus*) seem to follow the general pattern we found across all species. In the same way, the hypothesis might not work for other species. For instance, we found a high number of vocalisations of the short-toed treecreeper (*Certhia brachydactyla*) in a sampling point far away from 'pedrizas'. This sampling point was characterized to the presence of a water spring, and waterresources determines the presence and distribution of birds in Monfragüe National Park (J. Pérez-González, G. Rey Gozalo, D. Montes González, S. Hidalgo de Trucios and J. M. Barrigón Morillas, unpublished data). Different acoustic and biological features might determine for which species the effect of scree slopes are important in sound transmission.

A bird species use of natural elements within its habitat in the context proposed in this work could open lines of future research. Individuals might use these elements as 'instruments' favouring sound transmission. Each habitat includes an exclusive set of natural elements and the home range of a bird species might include different habitats. Therefore, different populations of the same species might use specific elements within their habitats

Table 3. Relationship between the mean distance of vocalisations to the 'pedrizas' and species richness. Results from the GLMM with species richness (presence–absence binomial variable) as the dependent variable, mean distance to 'pedrizas' as the fixed factor, and sampling location as the random factor.

Tabla 3. Relación entre la distancia media desde el lugar de las vocalizaciones hasta las pedrizas y la riqueza de especies. Resultados del modelo mixto lineal generalizado con la riqueza de especies (presencia y ausencia) como variable explicativa, la distancia media a las pedrizas como factor fijo y el lugar de muestreo como factor aleatorio.

Term	Estimate	SE	Variance	SD	z	p
Fixed factors						
Intercept	-1.189	0.499			-2.382	0.017
Distance to 'pedrizas'	1.000	1.530			0.414	0.679
Random factor						
Sampling location			0.071	0.267		

to favour sound transmission. This approach might imply the existence of cultural behaviours in birds, as previously proposed in traits related to dialects (Luther and Baptista, 2010).

The findings from this study may be a useful starting point for future studies on the modulation of bird behaviour depending on habitat features such as the presence of scree slopes. These future studies should be conducted using experimental designs or the collection of large amounts of data. Both approaches require an intense effort that might be justified by the findings from this study. Despite the possible bias related to the transmission distance of bird vocalisations, the high sound transmission on scree slopes, and the different habitat quality, the findings could be taken into account when designing experiments or collecting data. The use of scree slopes with larger surfaces, assessing of the mean territory size of the recorded bird species, counting individuals and the use of call rates, or the recording how long individuals spent singing on 'pedrizas' or in the surrounding forest could also help to control all possible biases.

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