Nota Curta / *Short Note*

Sound amplitude (dB) of male Western Capercaillie *Tetrao urogallus* calls

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Knowledge of the true amplitude (dB) of sound signals is necessary for calculating how far they can travel and the distance at which they can be detected, two crucial aspects for planning bio-acoustic sampling protocols, particularly if endangered species such as the Western Capercaillie are involved. In order to be able to measure the true emission amplitude of male Western Capercaillie *Tetrao urogallus* calls, we recorded 90 repetitions of the call of a single male using a calibrated microphone located 1 m away from the bird. In this way, we were able to determine for the first time the true amplitude of a calling male Western Capercaillie in the Alt Pyrenees Natural Park, which turned out to be 67.68 ± 0.83 dB. Considering the characteristics of our microphone, this gives an average maximum detection distance of 174.8 m, important information for optimising future bio-acoustic detection and monitoring studies.

Keywords: bird communication; bird song amplitude, bio-acoustics.

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Bioacoustics have been used as a non-invasive population monitoring method in ornithology for many years (Budk *et al.* 2015, Abrahams 2019, Abrahams & Geary 2020). Bird detection by passive acoustic monitoring allows us to improve the management of populations and habitats (Zhong *et al.* 2020, Verreycken *et al.* 2021), especially important for rare, declining, endangered or otherwise sensitive species. A bioacoustics approach is a non-invasive method that provides high-quality and long-term data, which can be critical for the conservation of these threatened species (Abrahams & Geary 2018, Abrahams 2019). This is the case of the Western Capercaillie *Tetrao urogallus*, a European boreal-forest grouse for which numerous management and conservation efforts are currently being undertaken (Sirkia *et al.* 2011, Gonzalez *et al.* 2016, Rosenberger *et al.* 2020). In recent years, passive autonomous acoustic monitoring has begun to be employed to study this bird's behaviour, status and population dynamics, as well as to improve its conservation management (Abrahams & Denny 2018, Abrahams 2019). Western Capercaillie populations in Central and Western Europe have declined during the twentieth century and the viability of its populations is threatened in many areas due to threats such as habitat destruction and predation (Jahren *et al.* 2016, Gil *et al.* 2020, García-Rodríguez *et al.* 2023). It is globally ranked as of Least Concern (BirdLife International 2016, BirdLife International 2024) but as Endangered in Catalonia (Decret 172/2022). Mating and reproduction are the most sensitive periods of its biological cycle and determine the species' annual population balance (Coppes *et al.* 2021, Strzała *et al.* 2023). During these periods, male Western

Capercaillies form leks in particular forest areas (Wegge *et al.* 2005) where male vocalizations are key components of their displays for both sexual selection and territorial purposes (Laiolo *et al.* 2011, Coppes *et al.* 2021). The characteristics of their calls have been shown to be associated with individual male or territory quality (Laiolo *et al.* 2011, Hart *et al.* 2020). Recent research has also shown the potential for using Western Capercaillie calls for population monitoring (Abrahams & Denny 2018, Abrahams 2019) and studies have demonstrated that male Western Capercaillie calls can be correctly identified by autonomous bioacoustics recorders. Call rates obtained during bioacoustic surveys correlate with the number of birds counted during traditional lek counts. Prior knowledge of the propagation and detection pattern of calls may help place microphones within a lek, thereby improving the coverage of the entire sampling area and minimising overlapping (Budk *et al.* 2015, Attenborough & Taherzadeh 2016, Zhong *et al.* 2020), and allowing for better estimates of the number of males at a lek. In the wild, animal calls are attenuated by meteorological factors (temperature, humidity and wind), forest characteristics and geometrical divergence (Tarrero *et al.* 2008, Tipton & Sparrow 2019). For these reasons, in order to perform accurate bio-acoustic experimental monitoring design and evaluation, the real sound amplitude in decibels (dB) of a bird's call must be obtained to be able to calculate sound propagation distance and the microphone detection distance (Attenborough & Taherzadeh 2016, Muhlestein 2018). However, a calibrated microphone has to be used and the sound source must be within 1 m of the microphone (Farina 2007, Farina & Tronchin 2013). Due to the complexity that such a measurement often entails, only in a very few cases has this important reference value ever been obtained in wild birds: examples include the White Bellbird *Procnias albus*, the loudest bird ever recorded (125 dB) (Podos & Cohn-Haft 2019), the Blackbird *Turdus merula*, the Chaffinch *Fringilla coelebs* (Schalz 2023) and Radde's Warbler *Phylloscopus schwarzi* (Opaev & Shishkina 2021). In this research, we aimed to describe for the first time the real amplitude (dB) of male Western Capercaillie calls and to calculate the maximum distance value for call detection by a given microphone (D_2), information that will improve the design of automated bioacoustic monitoring at lek sites.

We recorded a Western Capercaillie male in the Alt Pirineu Natural Park (Spain) in an area that still holds the largest Western Capercaillie population in the Iberian Peninsula despite a severe decline from an estimated 150 males in 2005 to 120 in 2015 (Gil *et al.* 2020). The forest study plot was located at 1800 m a.s.l. in the Vall de Cardós and consisted of mixed forests of *Pinus nigra* and *Betula* sp. with *Vaccinium myrtillus, Rhododendron ferrugineum, Juniperus communis* understorey. We used a previously calibrated Nevaton VR ambisonic microphone, protected with a Boya-WS1000 windshield connected to a Zoom F6 recorder set with at 48-kHz sampling rate, 32-bit float, 32-dB gain and 80 Hz high-pass filter, to obtain signals from birds more than 180 m away. On 15 May 2022, we recorded on a single night up to 90 call repetitions by a Western Capercaillie male singing just 1 m from the hide and microphone. This bird continued to call for >5 minutes, during which time its calls were recorded. We used the Aurora plugin, which operates in LIN (Z), and the A weighting for analysing the sound pressure and particle velocity signal with the Adobe Audition host software (Adobe Systems Incorporated 2003). We were thus able to determine that the true call amplitude of this one male Western Capercaillie was (average ± standard deviation) 67.68 ± 0.83 dB (min= 65.44, max=68.89). The call amplitude (Fig. 1) was observed to be slightly lower than other birds such as Blackbird (80 dB) and Chaffinch (90 dB) (Opaev & Shishkina 2021, Schalz 2023). The maximum average sound propagation distance (D_2) outdoors could thus be determined using the formula given by Farina & Tronchin (2013) and Attenborough (2014):

$$D_2 = D_1 \cdot 10^{((SPL_1 - SPL_2)/20)}$$

where D_1 is the distance from the sound source to the microphone (1 m in our case), SPL_1 is the real call amplitude (67.68 dB), and SPL_2 is the highest value between background noise and the lowest level of sound detection of the microphone. The background noise was measured 20 times by recording 30 seconds of ambient sound just before the male began to call (Guidorzi & Garai 2023), giving a value (average ± standard deviation) of 22.83 ± 0.71 dB (min = 21.64, max = 23.85). The lowest level of sound detection

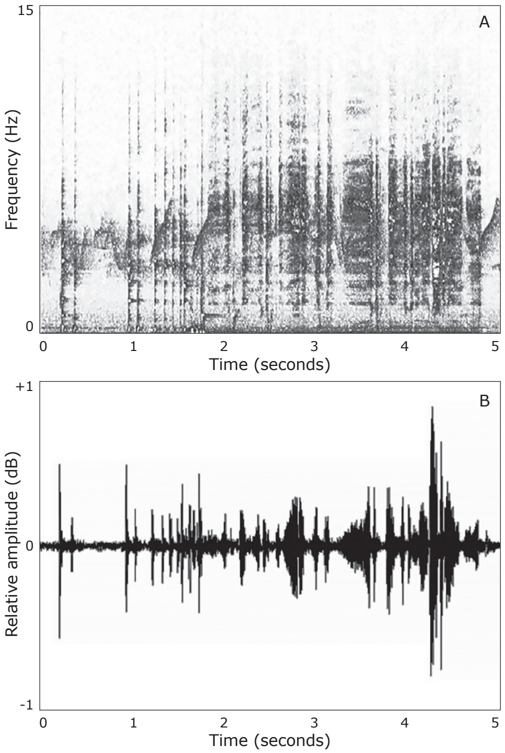

Figure 1. Spectrogram (A) and oscillogram (B) of a male Western Capercaillie call showing the variation in the frequency (Hz) and relative amplitude (dB) over time.
Espectrograma (A) i oscil·lograma (B) del cant del mascle de gall fer, on es mostra la variació al llarg del temps de la freqüència (Hz) i de l'amplitud sonora (dB).

of the microphone was 14 dB (as indicated by the manufacture's manual). Given these values, the average estimated maximum distance at which this male Western Capercaillie call could have been detected in our study forest by our microphone (D_2) was 174.8 m, with a minimum of 120.1 m (the lowest call intensity and highest ambient noise conditions) and a maximum of 230.4 m (the highest call intensity and lowest ambient noise conditions). The formula we used to estimate these values contemplates certain attenuation factors such as distance and background noise within the forest (Farina & Tronchin 2013, Attenborough 2014). However, other factors such as temperature, humidity and dendrological factors (White & Swearingen 2004, Tarrero *et al.* 2008, Tipton & Sparrow 2019), which were not considered in our calculation, could lead to some variation in the maximum propagation distance. The consideration of all these sources of variation would require an impulsive response analysis (Farina 2007, Shelley *et al.* 2013), beyond the scope of this preliminary research.

Although our study was limited to the measurement of a single male, relatively low inter-individual variability can be expected due to the similar body size of male capercaillies (Laiolo *et al.* 2011, Li *et al.* 2018) since call amplitude seem to be related to body size (Brumm 2009, Favaro *et al.* 2015). These results may help design bio-acoustic sampling protocols by determining how many microphones are needed to adequately cover a given surface area to avoid population underestimates. These reference values are also important if we aim to obtain good-quality recordings of calls at individual level (Abrahams 2019, Hart *et al.* 2020), which may be crucial for obtaining accurate population estimates and for the management of endangered species such as the Western Capercaillie.

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Resum

Amplitud de so (dB) de les vocalitzacions de mascles de gall fer *Tetrao urogallus*

El coneixement de la amplitud real (dB) dels senyals sonors és necessari per calcular la distància de propagació i la distància de detecció d'aquests senyals, aspectes crucials per poder planificar protocols de mostreig bioacústic, que poden ser molt útils quan es treballa amb espècies en perill d'extinció com ara el gall fer *Tetrao urogallus*. Per tal de poder mesurar la amplitud real dels cants dels mascles de gall fer, vam enregistrat 90 repeticions del cant d'un sol mascle mitjançant un micròfon calibrat, situat a 1 m de distància de l'ocell. D'aquesta manera, es va poder determinar per primera vegada la amplitud real del cant d'un gall fer mascle al Parc Natural de l'Alt Pirineu, que va resultar ser de 67.68 ± 0.83 dB. Tenint en compte les característiques del nostre micròfon, això va donar lloc a una distància mitjana de detecció màxima de 174.8 m. Aquesta informació permetrà optimitzar els futurs estudis de detecció i monitorització bioacústica del gall fer.

Resumen

Amplitud de sonido (dB) de las vocalizaciones de machos de urogallo *Tetrao urogallus*

El conocimiento de la amplitud real (dB) de las señales sonoras es necesario para calcular la distancia de propagación y la distancia de detección de dichas señales, aspectos cruciales para poder planificar protocolos de muestreo bioacústico, especialmente cuando se trata de especies en peligro de extinción como el urogallo *Tetrao urogallus*. Para poder medir la amplitud de emisión real de los cantos de los machos del urogallo, registramos 90 repeticiones del canto de un solo macho mediante un micrófono calibrado, situado a 1 m de distancia del ave. De esta forma, pudimos determinar por primera vez la amplitud real del canto de un macho de urogallo en el Parque Natural del Alto Pirineo, que resultó ser de 67.68 ± 0.83 dB. Teniendo en cuenta las características de nuestro micrófono, esto resultó en una distancia promedio de detección máxima de 174.8 m. Esta información permitirá optimizar futuros estudios de detección y seguimiento bioacústico.

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