

ACOUSTIC CHARACTERIZATION OF MALE GRASS WREN (*Cistothorus platensis*) CALLS DURING THE BREEDING SEASON IN A POPULATION FROM THE USPALLATA VALLEY, MENDOZA, ARGENTINA

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ABSTRACT: Calls are short, structurally simple vocal signals compared to songs, and play a key role in intra- and interspecific communication. The acoustic structure of calls within the genus *Cistothorus* has not been studied in South American populations. Here we describe the acoustic structure of the calls of the Grass Wren (*Cistothorus platensis*). We recorded males during the breeding season in a population from the Uspallata Valley, Mendoza, Argentina, and classified their calls according to their spectral and temporal parameters. We identified two different call types within the population, termed 'call A' and 'call B'. Call A had a longer duration, narrower bandwidth, and lower peak frequencies than call B. Calls with different structures suggest different behavioral contexts and/or functions. This study provides the first description of the species' calls and establishes a base-line for future studies assessing their function and possible variation among populations.

KEYWORDS: *acoustic structure, bioacoustics, Troglodytidae, vocalizations, vocal communication*

Calls are short, structurally simple vocalizations compared to songs, and convey a wide variety of social information (Catchpole & Slater 2003, Marler 2004a, 2004b). For example, when birds detect a predator, they may emit calls to summon individuals of the same or other species and thereby engage in coordinated mobbing behavior (Curio 1978, Griesser 2009, Dutour et al. 2016, 2019). Through contact calls, individuals of the same species can maintain social bonds and proximity, whether as a pair or as members of a social group (Farabaugh et al. 1994, Kondo & Watanabe 2009, Favaro et al. 2016). Furthermore, during the breeding season nestlings emit calls to solicit food from adults, while members of a pair may produce alarm calls to communicate the presence of a

threat near the nest to each other or to their nestlings (Leech & Leonard 1997, Marler 2004a, 2004b, Hollén & Radford 2009, Magrath et al. 2010). This diversity of functions is associated with particular behavioral contexts, often producing structurally different calls (Marler 1955, Morton 2000, Legarda Solarte 2016).

Natural selection has shaped this type of acoustic signal according to the receiver or receivers of the signal and the purpose of the call (Klump & Shalter 1984, Marler & Evans 1996, Koper et al. 2016, Piza & Sandoval 2016). Consequently, the physical structure of a call, defined by its spectral and temporal characteristics, is often related to the function it performs (Collias 2000, Morton 2000, Sung & Park 2005). For

example, in contexts of predation risk, high-frequency, narrow-band calls may confer an advantage to the caller by reducing the probability of being located (Briskie et al. 1999, Searcy & Yasukawa 2017). In contrast, other signals present characteristics that tend to increase the detectability and localization of the emitter, as is the case for many contact calls used to maintain social cohesion between individuals (Collias 2000, Elie & Theunissen 2016). In this context, describing the acoustic structure of a species' calls allows inferences to be made about the functions potentially associated with them (Marler 1955, Morton 2000, Sung & Park 2005).

The family Troglodytidae has been a model system for the study of vocal communication owing to the broad song repertoires of most of its species. It comprises around 75 species distributed throughout the Americas (Barker 2004), some with repertoires of hundreds of distinct song types (Kroodsmas et al. 2002). In particular, the closely related genera *Troglodytes* and *Cistothorus* have been the subject of several descriptive studies focused on complex song (*Troglodytes*: Platt & Ficken 1987, Tubaro 1990, Rendall & Kaluthota 2013, Sosa-López & Mennill 2014a, 2014b, Dos Santos et al. 2016; *Cistothorus*: Borror 1964, Kroodsmas & Verner 1987, Kroodsmas et al. 2001, Garrido Coria et al. 2021). Although alarm calls have been extensively studied in *T. musculus* (Fasanella & Fernández 2009, Corral et al. 2012, Fernández et al. 2012, Fernández & Carro 2022), only two studies have described calls in the genus *Cistothorus* in North America (*C. stellaris*; Walkinshaw 1935, and *C. palustris*; Luttrell & Lohr 2018).

Studies conducted in both genera show the existence of different call types within a single species associated with different contexts. In the Southern House Wren (*T. musculus*), studies reveal that the species is capable of producing two distinguishable call types (type I and type II; Fasanella & Fernández 2009, Corral et al. 2012, Fernández et al. 2012). Both are emitted in the presence of a threat, such as a predator, during the breeding season. Adults emit type I calls, possibly to inform the predator that it has been detected or to draw its attention away from the nest. In addition, it induces nestlings to reduce their activity and vocalizations within the nest (Serra & Fernández 2011). In the case of type II, its function is less clear, although it has been proposed that it could be directed toward the pair or the nestlings (Fernández & Carro 2022). On the other hand, seven calls have been described within the repertoire of the Marsh Wren (*C. palustris*). Some of these are associated with territorial vigilance, nest building, and courtship, and others are

linked to agonistic encounters with conspecifics or to the presence of humans (Luttrell & Lohr 2018).

The aim of this study was to describe the acoustic structure of the calls emitted by male Grass Wrens (*C. platensis*) during the breeding stage in a population from the Cuyo region, Argentina, in the locality of Uspallata, Mendoza province. Given that other species of Troglodytidae display multiple call types, we expected to identify acoustically distinct call types in the study population. Despite the wide Neotropical distribution of the genus *Cistothorus* (Brewer 2001, Llambías et al. 2025), knowledge of its calls is limited to two North American species, while this form of communication remains virtually unexplored in Neotropical species. Considering that the Grass Wren differs from the North American species in several life-history traits, such as its annual residency pattern and monogamous mating system (Llambías et al. 2018, 2019), as well as in its ecological context, it is relevant to provide information on its vocal repertoire (Sandoval & Graham 2024, Sandoval et al. 2024). This study is the first to report and characterize the acoustic structure of the calls of a Neotropical species of the genus *Cistothorus*. This constitutes a starting point for generating hypotheses about the possible functions associated with these vocalizations and contributes to improving our understanding of the diversity of communicative strategies present in Neotropical birds.

MATERIALS AND METHODS

Study species

The Grass Wren is a small (~10 g), insectivorous passerine distributed from southern Mexico to Tierra del Fuego, including the Malvinas Islands (Brewer 2001, Llambías et al. 2025). It inhabits tropical and temperate grasslands and wetlands. In the study population the species is a resident (Llambías et al. 2025), and its social mating system is predominantly monogamous, with moderate rates of extra-pair paternity (Llambías et al. 2018, Arrieta et al. 2022). Both sexes contribute to nest building and to feeding the nestlings (Llambías et al. 2018, 2020). Only males develop complex song to attract mates and defend a territory (Garrido Coria et al. 2021, 2025). Although both sexes emit calls, female behavior tends to be more cryptic, which makes it difficult to locate and individually identify their acoustic signals (PEL, PG & LAL, pers. obs.).

Study site

We conducted fieldwork in the Uspallata Valley,

Las Heras department, Mendoza province, Argentina (32°38'S, 69°22'W, 1800 m a.s.l.). The valley is irrigated by the Uspallata and San Alberto streams, forming around 120 ha of riparian grassland (Martínez Carretero 2000). The predominant vegetation along stream margins is pampas grass (*Cortaderia selloana*), with a lesser presence of other species such as Baltic Rush (*Juncus balticus*) and Seep Willow (*Baccharis salicifolia*). The climate is markedly seasonal (mean minimum temperatures of -2°C in winter and mean maximum temperatures of 25°C in summer), with scarce annual precipitation (~100 mm; Martínez Carretero 2000).

Field procedure

Since 2010, the 'Biología de Aves' (Bird Biology) research group at the Instituto Argentino de Investigaciones de las Zonas Áridas (IADIZA) has conducted monitoring studies on the breeding biology of Grass Wrens in Uspallata. In each breeding season (October–February), we captured adult individuals using mist nets and banded them with three colored bands and one numbered aluminum band for identification. During the periods 2011–2013 and 2016–2018 (six seasons) we recorded calls from 26 males (eight and 18 individuals, respectively) between 06:00 and 13:00 h. We obtained each recording opportunistically while following breeding pairs, positioning ourselves at a minimum distance of five m. We recorded each individual during a single breeding season, with the exception of two males recorded in more than one season. For the recordings we used a Marantz Professional PMD661 MKII digital recorder connected to a Sennheiser ME66 directional microphone with a K6 power module. We made all recordings in .wav format, with a bit depth of 24 bits and a sampling rate of 48 kHz. To capture possible intra-individual variability, we randomly recorded 15 individuals in two or more different months and ten individuals on different days within the same month throughout the breeding season. We obtained a total of 90 recordings (>10 h; one to six per male) corresponding to 26 individuals.

Acoustic analysis

We generated spectrograms of all recordings in the bioacoustic software Raven Pro (version 1.6.5, K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology 2026), using the following parameters: *Hann* window type, *window size* 512 samples (10.70 ms), *3 dB filter bandwidth* 134 Hz, *overlap* 50%, *hop size* 257 samples (5.35 ms), *DFT*

size 1024 samples, and *grid spacing* 46.9 Hz. Calls in this species are composed of simple notes that can be repeated over time at variable rates. Therefore, in each call recording, we used the note (defined as a single trace within a spectrogram) as the measurement unit (Marler 2004c, Luttrell & Lohr 2018). We randomly selected a minimum of five and a maximum of 20 notes per recording and measured temporal (note duration (s)) and spectral parameters (minimum frequency (Hz), peak frequency (Hz), 50% and 90% bandwidth (Hz), and the minimum and maximum of the peak frequency contour (Hz)). We obtained the selection tables for each recording and exported them for statistical analysis. We deposited all analyzed recordings in the IADIZA Bioacoustics Collection.

Statistical analysis

We performed all statistical analyses in the RStudio environment (version 4.5.1, R Core Team 2025). Using the *Rraven* package (Araya-Salas 2020) we imported the selection tables and subsequently calculated the mean of each acoustic variable per recording with *dplyr* (Wickham et al. 2023). To reduce the dimensionality of the data and explore its multivariate structure, we performed a Principal Component Analysis (PCA; R Core Team 2025). Because the variables had different units of measurement, we standardized them to facilitate comparison. To classify the different call types, we retained the components that explained at least 70% of the total cumulative variance and used them in a model-based grouping or *clustering* analysis, using the *mclust* package (Scrucca et al. 2023). Prior to clustering, given that the data correspond to more than one recording per individual, we assessed how much of the variation detected in the PCA was due to differences among individuals using Generalized Linear Mixed Models (GLMM). In these models we included the values of the principal component axes as dependent variables and individual identity as a random factor. From these models, we calculated intraclass correlation coefficients (ICC). We repeated this procedure using each acoustic variable individually as the response variable (Supplementary Material Table S1).

The clustering analysis used is an unsupervised classification method that fits different Gaussian Mixture Models (GMM) and uses the Bayesian Information Criterion (BIC) to select the model and the optimal number of groups or clusters that best describe the data. In addition to assigning each recording to a group, the model provided the probability of membership to each cluster, which allowed

us to estimate the uncertainty associated with each assignment.

RESULTS

The PCA showed that the first two principal components (PC1 and PC2) explained 74.66% of the variance in the data. PC1 (52.04%) varied positively with note duration and negatively with the frequency variables (minimum frequency, peak frequency, 50% and 90% bandwidth, and the minimum and maximum of the peak frequency contour). All variables showed loadings of similar magnitude except minimum frequency, whose contribution to the component was small. PC2, in contrast, accounted for a smaller proportion of the variance (22.62%), but varied mainly positively with the minimum and maximum of the peak frequency contour, and negatively with the bandwidth variables (50% and 90%; Table 1). The density of scores along PC1 indicated a bimodal distribution of recordings (Supplementary Material Fig. S1), which was supported by Hartigan’s dip test ($D = 0.070$, $p = 0.002$).

Individual identity explained a negligible proportion of the variation in PC1 ($ICC \approx 0$) and a moderate

proportion in PC2 ($ICC \approx 0.13$), indicating that the main structure of acoustic variation was not associated with differences among individuals. When acoustic variables were evaluated individually, individual identity likewise did not contribute to the variation, except for minimum frequency (Supplementary Materials Table S1). In the clustering analysis, we found that the model with diagonal distribution and variable volume and shape (VVI) with two clusters provided the best fit according to the BIC (Table 2). We confirmed the selection of this model based on the BIC difference relative to the single-cluster model ($\Delta BIC = 27.32$). Cluster 1 included 44 recordings, while cluster 2 included 46. The mean classification probability was 0.98, i.e., on average each observation had a 98.20% probability of belonging to its assigned cluster. Consequently, the mean classification uncertainty was low (1.80%).

Because most of the variability was explained by PC1 (52.04%), the separation between the two clusters occurred mainly along this component. The two clusters we identified through the GMM correspond to the bimodal structure present in the first principal component (PC1), generating two call groups (Fig. 1), arbitrarily termed calls ‘A’ and calls ‘B’:

Table 1. Loading coefficients for the first two principal components (PC1 and PC2) obtained through a principal component analysis (PCA), used to reduce the dimensionality of the variables describing the structure of calls emitted by male Grass Wrens (*Cistothorus platensis*) in Uspallata, Mendoza, Argentina.

Variables	PC1	PC2
Note duration	0.39	-0.06
Minimum frequency	-0.01	0.56
Peak frequency	-0.49	0.12
50% bandwidth	-0.37	-0.39
90% bandwidth	-0.42	-0.42
Minimum of peak frequency contour	-0.42	0.09
Maximum of peak frequency contour	-0.32	0.56
Variance explained (%)	52.04	22.62
Cumulative variance (%)	74.66	

Table 2. Bayesian Information Criterion (BIC) values for the three best call-classification models for male Grass Wren (*Cistothorus platensis*) calls, obtained using Gaussian Mixture Models (GMM), VII (diagonal distribution, variable volume and shape), EVI (diagonal distribution, equal volume, variable shape), and VII (spherical distribution, variable volume, equal shape).

Model	Number of clusters	BIC
VVI	2	-657.23
EVI	2	-659.59
VII	2	-661.01

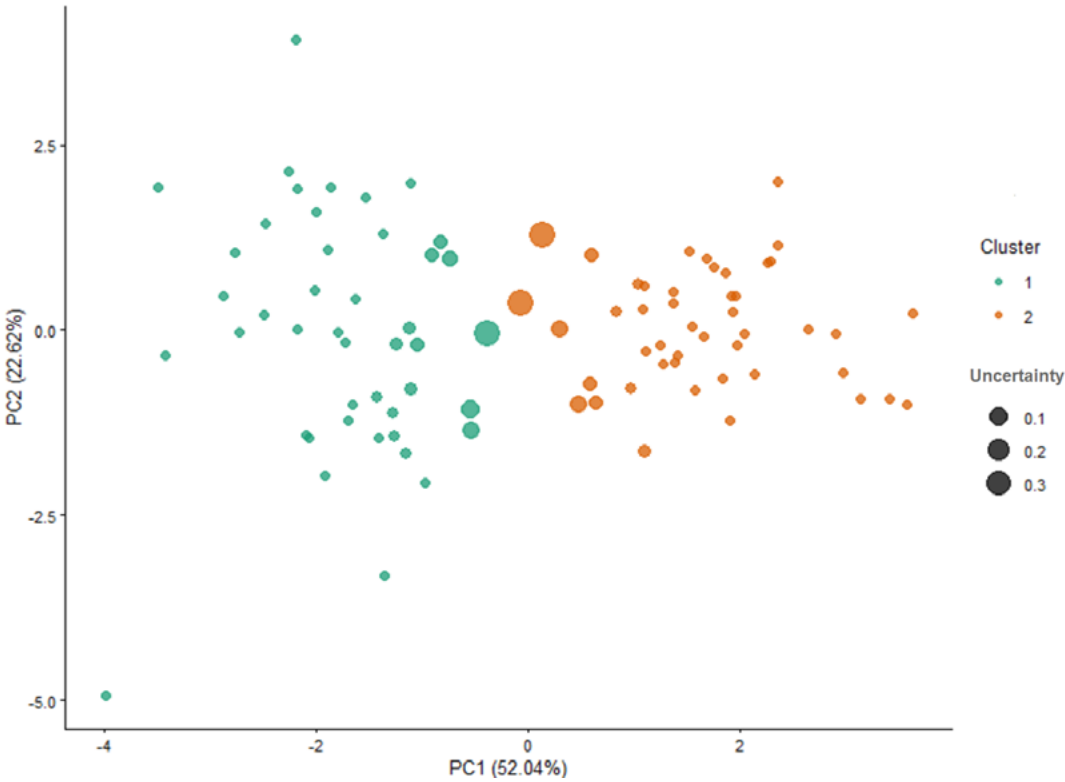


Figure 1. Assignment of male Grass Wren (*Cistothorus platensis*) calls to two clusters in two-dimensional acoustic space (PC1 and PC2). Each point in the plot corresponds to a recording ($n = 90$) made in Uspallata, Mendoza, Argentina. The color of each point indicates the assigned cluster (green or orange), and the size reflects the uncertainty of cluster membership.

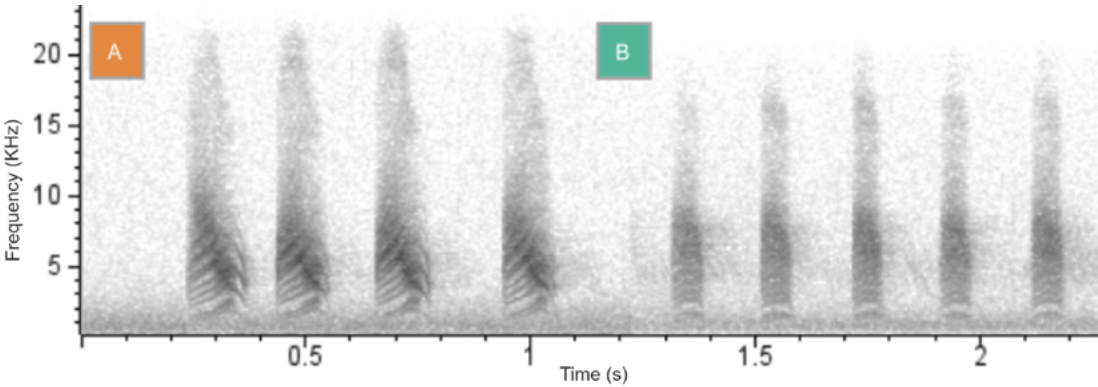


Figure 2. Representative spectrogram of calls emitted by male Grass Wrens (*Cistothorus platensis*) in Uspallata, Mendoza, Argentina. In this study we identified two call types: (A) call A (cluster 2) and (B) call B (cluster 1). Image generated with Raven software (version 1.6.5, K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology 2026).

Cluster 1 ('call B'): notes of shorter duration and greater bandwidth, with high peak frequencies.

Cluster 2 ('call A'): notes of longer duration and narrower bandwidths, showing lower peak frequencies (Fig. 2, Table 3).

The resulting grouping represents different call types rather than differences among individuals, given that 20 of 26 individuals emitted calls classified in both clusters (Supplementary Material Table S2).

DISCUSSION

In this study we describe the acoustic structure of male Grass Wren calls in the Uspallata Valley, Mendoza, Argentina. Our results reveal the presence of two different call types (A and B), distinguishable both temporally and spectrally. A calls have a longer duration, narrower spectrum, and lower pitch, whereas B calls have a shorter duration, broader spectrum, and higher pitch. However, the presence of vocalizations with an intermediate acoustic structure between A and B could reflect the state or condition of the emitter. This could reflect variation associated with emission rate due to constraints related to lung and respiratory capacity during vocal production (Hartley & Suthers 1989, Podos 1997, Illes et al. 2006, Sierro et al. 2023). Alternatively, these vocalizations could be transitional notes between call types. However, such calls were infrequent.

The structural differences found between A and B calls suggest that they are possibly emitted in different behavioral contexts and/or serve different functions. Systematic field observations made during the monitoring of breeding pairs over six seasons indicate that call A was the least frequent vocalization. It was associated with evasive behavior, with individuals hidden

in the vegetation (PEL & LAL, pers. obs.). This pattern suggests a possible intraspecific short-distance communication function, which could be directed toward the female, nestlings, or fledglings. In contrast, call B was emitted more frequently in the presence of potential dangers (e.g., people near the nest) and from exposed perches on the vegetation (PEL & LAL, pers. obs.), suggesting that it could serve as an alarm signal or a long-distance recruitment function directed at conspecifics. Likewise, both calls were easily locatable by the human ear, so their emission could also be aimed at drawing the receiver's attention toward the vocalizing individual (PEL & LAL, pers. obs.).

Variation in the acoustic structure of these vocalizations may also be shaped by the physical properties of the habitat, such as vegetation structure, wind, humidity, or natural or artificial noise. It has been suggested that spectral and temporal properties have evolved to optimize sound transmission in a given habitat (Acoustic Adaptacion Hypothesis; Morton 1975, Slabbekoorn et al. 2007, Hardt & Benedict 2021). Nevertheless, few studies in oscine birds have evaluated the role of habitat in call variation, either at a macrogeographic (Irwin et al. 2008, Luttrell & Lohr 2018) or a microgeographic scale (Naguib et al. 2001). In this context, the differences observed between call types A and B could also be modulated by local acoustic conditions of the habitat type in the Uspallata Valley. In this regard, future studies should compare the acoustic structure of calls among different Grass Wren populations across its range to establish whether the call types described here are shared by other populations, and to evaluate the contribution of habitat to their geographic variation.

In the present study, the analyses were based on calls emitted only by male Grass Wrens. Males and females may emit different call types or even differ

Table 3. Mean values ($\pm$ SD) of the acoustic variables for the two call groups (termed A and B) of male Grass Wrens (*Cistothorus platensis*), classified using Gaussian Mixture Models (GMM).

Acoustic variables	Cluster 1 (Call B, n = 44)			Cluster 2 (Call A, n = 46)		
Note duration (s)	0.06	$\pm$	0.01	0.11	$\pm$	0.03
Peak frequency (Hz)	6434.44	$\pm$	627.02	4342.95	$\pm$	534.87
50% bandwidth (Hz)	1961.89	$\pm$	468.97	1422.79	$\pm$	271.45
90% bandwidth (Hz)	4826.83	$\pm$	797.04	3400.61	$\pm$	393.15
Minimum of peak frequency contour (Hz)	3936.49	$\pm$	1156.53	2768.69	$\pm$	529.10
Maximum of peak frequency contour (Hz)	7269.51	$\pm$	596.85	6082.94	$\pm$	793.62

in the frequency with which they emit the different call types (Marler 2004b, Amy et al. 2018, Austin et al. 2021). In both the Southern House Wren and the Marsh Wren, call emission depends on sex (Fernández et al. 2012, Luttrell & Lohr 2018). Field observations made during the monitoring of the Grass Wren indicate that females produce two calls apparently similar to those described for males (PEL & LAL, pers. obs.). Nevertheless, it remains unknown whether there are structural differences between the vocalizations of the two sexes. This introduces an important limitation in the functional interpretation of the calls, so studies on female vocalizations are needed to assess whether sex-associated variation is also present in the study population.

This study constitutes a first step for future research to explore the function associated with Grass Wren calls, as well as their possible variation at the geographic level and between sexes. Our work contributes to the knowledge of vocalizations in a South American species of the genus *Cistothorus* and provides new evidence to help understand the evolution and function of vocal communication in birds of the Global South.

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USE OF ARTIFICIAL INTELLIGENCE

During the preparation of the manuscript, we used ChatGPT (OpenAI) as a support tool for statistical analyses, improvements in writing, and translation into English.

ETHICAL PERMITS

The permits were granted by the Secretariat of Environment, under the Directorate of Renewable Natural Resources, Government of Mendoza (Resolutions Nos. 946, 459, and 1564).

SUPPLEMENTARY MATERIAL

You can access the supplementary material for this article by visiting the link <https://doi.org/10.56178/eh.v41i2.1545>.

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