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ECOSYSTEMS

Structure and function of calls of the Masked Gnatcatcher *Polioptila dumicola* in Mid-eastern Argentina

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Abstract. Acoustic communication plays a key role in the life of birds and it is useful in phylogenetic and evolutionary investigations. This study described the structure and function of *Polioptila dumicola*´s call repertoire in riparian environments from the Mid-eastern of Argentina. Male calls (N=644) were recorded in the field during the pairs nuptial interactions; nests exploration and previously capture of male. Then, specific function was assigned to different calls using standardized methods of acoustic classification and behavioral observations. Twelve different types of calls were classified. Alert and call to female were the most frequent calls and they represented 12.04% and 10.24% of recordings. Anguish call was also recorded in this species. These are the first results regarding to the calls and repertoire of *P. dumicola*. These data could be used for new studies on environmental selection pressures and for conservation of this species and its habitats.

Key words: Alarm, calls, contact, behavior, *Polioptila dumicola.*

INTRODUCTION

Animals communicate through a diversity of signals and different sensory channels (Partan & Marler 2005). Signals of acoustic communication are used for species recognition, mate selection, and territorial and anti-predator defense. These signals are likely shaped both by natural and sexual selection (Ryan & Brenowitz 1985, Mathevon et al. 2008, Podos 2014). The emitter mechanisms likely evolve to increase efficiency and reliability of the information delivered whereas reception mechanisms evolve so that receivers can produce appropriate behavioral or physiological responses (Endler 1993, Maynard-Smith & Harper 2003). In this sense, animal communication is under some selective pressure (e.g. adapting the signal to reach great distances; adjusting signals to avoid localization by predators), which becomes highly relevant in environments acoustically contaminate such as those that occur in urban sites (Boncoraglio & Saino 2007). In this context, the study of vocal communication is an important component to different disciplines such as evolutionary ecology and conservation biology, especially in birds (Naguib & Riebel 2006).

Bird vocalizations, especially of passerines, are among the most complex sounds produced by animals (Briefer et al. 2010). This complexity of sounds in passerine’s birds emit can be classified in two types of vocalizations: song and calls. The songs tend to be long, complex, and emitted by males in the breeding season. Generally, songs occur over long periods of time and with a characteristic daytime rhythm (Catchpole & Slater 2008). Unlike songs, calls are simpler, with fewer notes, shorter duration, more stereotyped within species, and genetically predetermined (Marler 2004). Thus, animals are able to produce calls without intensive learning. Also, calls occur in a variety of environmental situations throughout the day (Beckers & Gahr 2010).

Calls are essential within the bird population because they give information related to parental behavior, nepotism, altruism, and cooperation (Wheeler 2008, Goedert et al. 2014). They can be classified as alarm and contact calls (Marler 1955, 2004). Alarm calls occur during hostile conspecifics and heterospecifics interactions when, for example, individuals detect potential predators (Kondo & Watanabe 2009). Alarm calls are loud and repetitive, audible near the caller, and difficult to locate (Marler 1955). The type of alarm call can transmit information about the predator's type (Suzuki 2011), size (Templeton et al. 2005), and distance (Leavesley & Magrath 2005). Due to their role in interactions such as predation or competition, alarm calls probably result from adaptive processes (Klump & Shalter 1984). Several studies have classified alarm calls considering the sound (e.g. "whistle", "rough sound"), the behavior of both the emitter and the receiver (e.g. "mobbing", "persecution") and the context in which they occur (e.g. "anguish", "distress" (Caro 2005, Wheeler 2008). Acoustically, alarm calls are similar in structure among species (Davis 1988, Jurisevic & Sanderson 1998), but there is considerable interspecific variation in the use of these types of calls. For instance, the proportion of individuals that emit alarm calls can vary among species (Rohwer et al. 1976, Grieg-Smith 1984), an aspect that is important to characterize to assess selective pressures within populations and among species.

On the other hand, contact calls are emitted between conspecific individuals and they encode several types of information (recognition, signaling about food, maintaining social cohesion, synchronizing and coordinating of flight). These calls are soft and wideband, audible only at close range (Hamilton 1962). The contact signal is recognized as unique, and the receiver learns the cues and uses them to identify the emitter during future interactions (Tibbetts & Dale 2007). Several studies in some species like *Aratinga canicularis* and *Brotogeris jugularis* have shown that individuals exchange contact calls with overflying groups while feeding, probably to recruit other individuals to the food site (Bradbury & Allen 2003).

Studies focused on the calling behavior of birds are more limited than those studying the singing behavior (Neudorf & Sealy 2002, Nocera et al. 2008, Martin et al. 2011), despite its importance for predation or competition events. Moreover, the vocal repertoire of Neotropical birds is much less known than that of birds from Northern temperate areas.

Polioptila dumicola is a small size bird species belonging to a family of small passerine birds (Polioptilidae) that do not exceed 20 species. According to BirdLife International and the Red List of Threatened Species (IUCN 2020) their population trends are threatened and in decline due to human activities such as deforestation of forests, and wetland fires. *Polioptila dumicola* is distributed in tropical and subtropical climates throughout the Americas, except in the extreme south and the high regions of the Andes. In Argentina, this bird species has a wide distribution from the north to San Juan, San Luis, Córdoba, and Buenos Aires Provinces (Ridgely & Tudor 1997).

P. dumicola, for example, has been described as a bird species with 'many calls', however, this species has never been cataloged and alarm call as 'meowing' (contact call between both sexes as 'tripp' and 'song') was only described (Fraga & Salvador 2013).

In the present study, the adult call repertoire from mid-eastern of Argentina was cataloged and each different call was related to its function for the first time. As a social species, a large amplitude in the call repertoire is expected according to the social complexity hypothesis, where groups with complex social systems require more complex communicative systems to regulate interactions and relations among members. So this type of behavior of *P. dumicola* is positively related to the amplitude of the call repertoire in birds (Dunbar 1998, Freeberg et al. 2012). In this context, establishing the repertoire of this species and the different functions of calls provides unknown aspects related to its behavioral ecology and systematic.

MATERIALS AND METHODS

Study area

The study was performed in riparian areas of the Parana´ River situated on the Mid-eastern of Argentina (31° 39'S; 60° 35'W). The records were carried out on one side of a National Route (NR) (NR 168, Santa Fe Province, Argentina). This area has 7000 ha and includes a complex system of islands, lagoons, ponds, and permanent freshwater marshes, interspersed with riparian woodland and gallery forests (Peltzer & Lajmanovich 2004). Different tributary orders, streams and rivulets delimited the riparian areas. The intermediate zones or flooded transitional zones are flat and exposed to periodic floods (Sánchez et al. 2009). The study area has forest fragments with species such as *Albizia inundata, Croton urucurana, Sapium haematospermum, Celtis tala* and *Vachellia caven*, among other trees, shrubs, and grasses. The climate is temperate, with a mean annual temperature of 27.5°C (SD±3) and mean annual precipitation of 995 mm (data provided by Facultad de Ciencias Hídricas de la Universidad Nacional del Litoral, FICH-UNL).

Study design

A total of 50 males o*f P. dumicola* were observed and recorded during the pre-breeding and breeding periods (August – February of 2016 and 2017). The inner area of a forest fragment situated more than 200 m away from the route was selected due to the entrance area easily (Olguín 2016). The nests with their corresponding couple were identified examining areas near to active females and then enumerated. Mist nets were used to capture and mark individuals with color rings to avoid repeating record of the same individual (Ralph et al. 1996) and to observe the vocal behavior of the birds during capture. The focal method was used to observe male´s behaviors (occurrence and duration of all types of behavior patterns) (Altmann 1974, Martin & Bateson 2007). The couples were monitored every two days, in periods of up to 2.5 hours at a distance of 15-30 m from the previously identified male.

Recording methods

Vocalizations were recorded in different situations: 1) during nuptial interactions, 2) during the nest's exploration and 3) prior to the male capture. Each adult male was recorded for three minutes each individual or until 20 calls were registered, two times a week between 07:00 and 12:00 hr. A unidirectional ME - 66 microphone Senheiser with a K6 - C condenser and a Korg MR - 1000 digital recorder (sampling rate: 44.1 kHz, 16 bits) was used. The recording equipment was placed close to the selected individual and only recordings with the best level of signal-to-noise ratio (SNR 20-30 dB) were analyzed. Recordings were achieved in wave format, mono quality, and 16 bits. This instrumental does not compress the sound, which avoids the loss of frequencies that, although are not audible to humans, are components of the songs of the birds (Budney & Grotke 1997).

Measurement of acoustic parameters

A call has been defined as a stereotypical vocalization used in intra-group communication (Tobias et al. 2011), consisting of either a single note given at isolation or repetition, as well as given in a consistent sequence of ordered notes being the note a solid line on a spectrogram (Vargas-Castro et al. 2012, Sosa-López & Mennill 2014). Each call was analyzed using the Raven Pro 1.5 program (Bioacoustics Research Program 2014) employing the following parameters: type window Hann, window size, and Fourier transform of 512 samples: overlap of 50% (hop size of 256 samples) and spacing 86.1 Hz (Garcia 2016). The acoustics parameters measured were A) number of notes, B) duration of the call (s), C) maximum frequency (kHz), D) minimum frequency (kHz) and E) peak frequency (kHz, i.e. the frequency for which amplitude is greatest). Frequency measurements were accurate at 0.012 kHz increments, time measurements at 1 ms and the spectrogram figures were cut out at 12.5 kHz to obtain an adequate visualization. Standard parameters were recorded with an onscreen cursor which has been considered to quantify the acoustic structure of calls (Langmore et al. 2003, Gloag & Kacelnik 2013). Average values were calculated for each of the five acoustic variables pooled together by category. T-tests were performed in R (R Studio Team 2020) to compare the acoustic parameters among alarm and contact calls.

Classification and function of calls

Calls were classified by 1. Number and type of notes: number of minimum continuous sound units of a call; 2. Structure observed in the spectrogram (note form): to interpret the form of a note on the spectrogram it was considered that *a*. high-pitched sounds (with a higher frequency) appear higher on the y-axis, *b*. a short whistle of the constant pitch will appear as a pure, unmodulated frequency trace on the spectrogram, *c*. a whistle which starts at a higher frequency and drops to a lower one is said to be frequency modulated and appears on the spectrogram as a slope from left to right. *d*. If more rapid modulations appear, as in a fast vibrato, *e*. unclear short sound like click (if several occur close together a buzzing sound is produced), *f*. when a sound has higher frequencies as multiples of the first or fundamental frequency is called harmonics. 3. Audition of call evaluated by a human observer (identification of clear auditory differences from the playback of recordings). Categories were validated based on two observers who received a call example by category. In order to classify function of calls, preliminary observations were used to identify a set of behaviors and vocal responses that could easily be distinguished. Behavioral responses were inferred during field observations (see above) by assessing the behavior of other individuals in the immediate second following a call, but these responses should be interpreted cautiously in case they were triggered by the same context as their associated call. The potential for subjectivity in these classification methods was recognized, but a simple classification method to outline the minimum number of differences a contextually view associated with clear auditory was selected.

RESULTS

Recorded calls of *P. dumicola* males (N=50) were classified in 12 different types (Tables I and II). Five calls were categorized as alarm (alert, alert short distance, danger call, distress call, and anguish call), five calls as contact (call to female, territorial call, incubation, nest building, long-distance) and two calls could not be categorized.

Table I. Characteristics of 12 call types of *Polioptila dumicola* males. Values are expressed as mean ± SD.

Type of call	Number of notes	Total duration (s)	Maximum frequency (kHz)	Minimum frequency (kHz)	Dominant frequency (kHz)	Bandwith (kHz)	N (call)	Emission percentage (%)
Alert call	1.82 ± 0.24	0.51 ± 0.03	5.70 ± 0.86	2.82 ± 0.12	4.58 ± 0.80	2.91±0.63	65	12.04
Short distance alert	2.44 ± 0.17	0.11 ± 0.01	5.50 ± 0.24	3.33 ± 0.27	4.75 ± 0.15	2.99±0.22	80	9.7
Danger call	5.5 ± 2	1.03	5.73 ± 0.17	2.92 ± 0.08	4.34 ± 0.21	1.23±0.64	64	9.6
Distress call	9	2.05	7.14	2.67	4.82	2.15±0.56	64	9.6
Anguish call	5 ± 1	1.11 ± 0.16	4.62 ± 0.21	2.28 ± 0.21	5.55 ± 0.11	1.12±0.25	56	8.43
Call to female	8.33 ± 1.2	1.60 ± 0.16	5.65 ± 0.20	2.64 ± 0.17	4.82 ± 0.09	1.56±0.27	68	10.24
Long distance	8.10 ± 0.43	1.51 ± 0.06	4.88 ± 0.06	2.77 ± 0.05	4.46 ± 0.52	1.01±0.42	64	9.6
Territorial call	9 ± 3	1.45 ± 0.17	5.25 ± 0.086	2.28 ± 0.38	4.34 ± 0.04	2.06±0.60	65	9.8
Nest building	11 ± 0.24	1.70± 0.24	5.6 ± 0.23	3.12 ± 0.15	4.53 ± 0.07	0.68±0.08	59	8.8
Incubation	5.60 ± 0.45	1.57 ± 0.13	5.07 ± 0.11	2.77 ± 0.13	4.56 ± 0.27	1.80±0.75	62	9.3
Unassigned call	7.3 ± 0.88	1.58 ± 0.19	4.96 ± 0.07	2.91 ± 0.09	4.33 ± 0.11	1.22±0.24	8	1.2
Unassigned call	8±0.78	1.68±0.28	4.82±1.31	3.44±0.07	4.56±1.05	1.12±0.47	9	1.3

Table II. Data were collected from 50 couple of *P. dumicola* throughout the breeding season. Percentages (%) indicate how often a context or response was associated with a specific call.

Type of call		Category	Context of call production	Receiver behavior response	Call number associated a specific context	Total number of calls recorded
Alert call	Alarm	Presence of predators (66%), Presence of humans (33%)	Females vocalize Far from the nest	N= 43N=22	65	
Short distance alert	Alarm	Food search (35%), Visual contact (65%)	Female or juvenile emit the same call	N=52N=2^{8}b	80	
Danger call	Alarm	Eggs predation (67%)	None	N=43	64	
Distress call	Alarm	Capture mist nest - moobing (90%)	Moobing	N=58	64	
Anguish call	Alarm	Predation of chicks or couple (83%)	None	N=47	56	
Call to female	Contact	Prior to alert or danger call (75%)	Same call of female	N=51	68	
Long distance	Contact	Female out of territory (100%)	Female approaches to the nest	N=64	64	
Territorial call	Contact	In the presence of another male (64%)	Same call of other male, that Move away of the nesting site or stars a conflict	N=41	65	
Nest building	Contact	Search for construction material (64%)	Same behavior	N=38	59	
Incubation	Contact	Change of individual that incubates (90%)	Female enters to incubate	N=56	62	

Acoustics characteristics of calls

The sonograms and oscillograms analyzed were obtained from N = 664 calls (Range: 50 – 80 for an individual). The maximum frequency of the calls varied between 4.8 and 7.14 kHz and the minimum frequencies between 2.28 and 3.3 kHz. In addition, the highest dominant frequency was 5.5 kHz and the bandwidth of all calls ranged between 0.68 and 2.99 kHz. The longest duration was 2.05 s and the highest number of notes was 11 (Table I). Of the acoustic variables compared, only the number of notes differed among types of calls, had contact calls with higher number of notes ($\overline{X}$ = 8.40 ± 2.7) than alarm calls ($\overline{X}$ = 4.75 ±1.8, t-test7.04 = -2.37, P = 0.04).Alarm calls had harmonic and broadband structures, and they were noisy, harsh and abrupt. Contact call had frequency-modulates structures that sounded like a whistle.

Alarm calls

Alert call

It is composed of high-frequency harmonics, short duration, and variation of dominant frequency (Fig. 1a). This sound was associated with threatening situations involving either terrestrial or aerial predators of eggs as *Pitangus sulphuratus* or *Didelphis albiventris* in the 66% (N =43) of observed call, whereas the other 34% (N=22) is emitted in presence of people nearby (all located more than 30 m, Table II). It was emitted by males and can play a potential alarm role for the female.

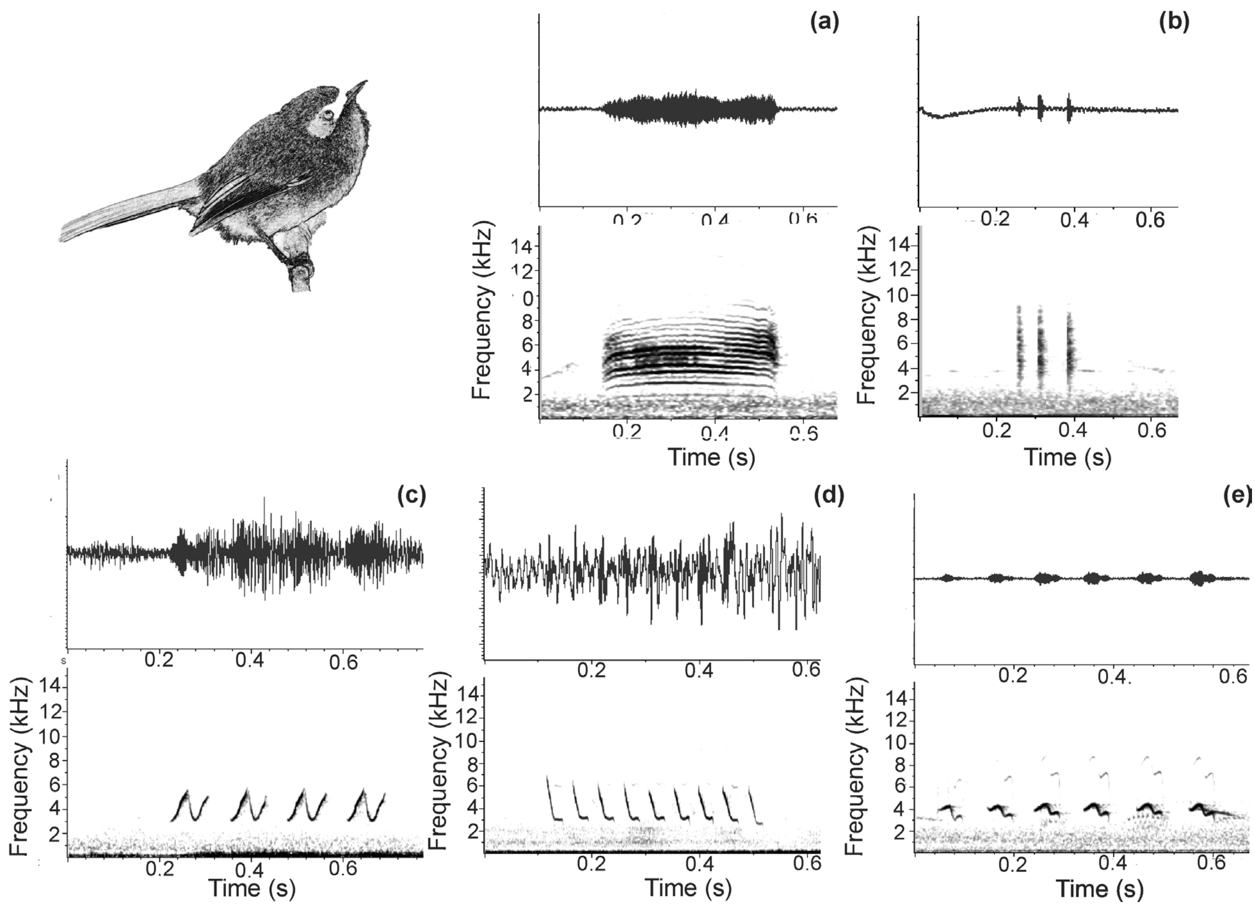

Figure 1. Oscillogram (upper part) and spectrogram (lower part) of alert (a), short-distance alert (b), danger (c), distress (d) and anguish (e) calls of *P. dumicola*.

Short-distance alert: It was characterized by short clicks (Table I, Fig. 1b). It is audible no more than 20 m by the human ear. It was associated with both the close presence of the couple or juvenile individuals and the territorial displacements during food search in the 35 % (N= 52) of the recorded call. But, in the remaining 65%, this call was related to eye contact (Table II).

Danger call

It is composed of complex modulated frequency notes, and it is given in the presence of a predator (Fig. 1c). In this situation, individuals of the *P. dumicola* are not easy to visualize and are located in trees very close to the nest. This sound is associated with situations related to predation by snakes such as *Philodryas aestiva* (Table II).

Distress call

This consists of strong-tone notes characterized by a high frequency and a long duration. This call was associated with extreme stress (e.g. during captures in mist nets or during chick manipulation, Table II). In general, an effect called "mobbing" (behavior to drive away potential predators) occurred simultaneously and it was characterized by the arrival of the couple members and other species at the site of conflict (Fig. 1d). On each of these occasions, other individuals of the same social group quickly approached to the distressed bird, chattering and mobbing the predator. This call appears to function as a signal of immediate danger, and it is only given during actual or attempted predation.

Anguish call

It consists of sounds with jumps of frequency. Emitted by the male before chick or adult predation events (Table II and Fig. 1e). On each of these occasions, the individual emitting the sound was located next to the predated nest.

Contact calls

Call to female

It is emitted by the male, and it has eight notes in the form of "V" (Fig. 2a). It has the function of attracting the female and it was recorded during moments before the emission of alarm or danger calls (Table II).

Long distance

It is constituted by notes of descending modulated frequency in the form of "inverted V" (Fig. 2b). It was observed when one member of the couple was not present in the territory (Table II). Individuals perch on higher branches about the location of the nest. This call occurs in conditions where there is no visual contact between members of the couple, and the receiver responds approaching to the site where the call comes from.

Territorial call

It is composed of 9 to 12 notes of modulated frequency. It was observed at the beginning of the reproductive season, during the beginning of the nest building and in the presence of another male (Table II). This causes that other individuals of the same sex move away from the nesting site or from the conflict between both males (Table II, Fig. 2c).

Nest building

It is characterized by long calls (10-11 notes) composed of short whistles and ascending modulated frequencies. It was associated with the moments of nest construction such as during searching of elements useful for that purpose (Table II, Fig. 2d).

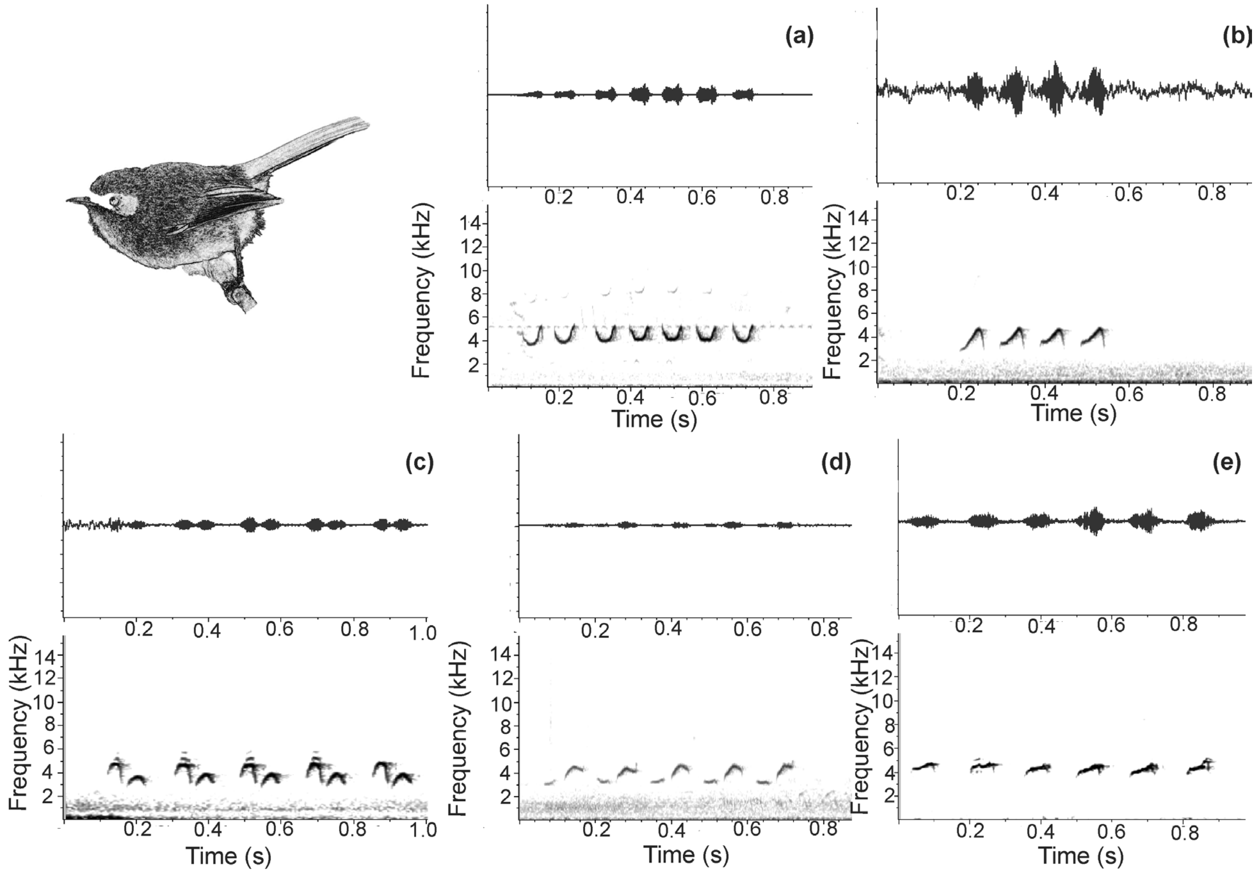

Figure 2. Oscillogram (upper part) and spectrogram (lower part) of call to female (a) and long distance (b), territorial (c), nest building (d) incubation (e) call of *P. dumicola*.

Incubation

It is a short and ascending call produced by males and females. It is not frequently issued call (Table I) and it was associated with an egg incubation period (90% of observed call). In *P. dumicola* the care of eggs and chicks is biparental, and usually, the male usually emitted this signal inside the nest and then the female arrives to incubate (Table II, Fig. 2e).

Unassigned calls

Unclassified calls are grouped in phrases. Other calls are short whistles and are preceded by high and acute modulated frequencies (Fig. 3).

DISCUSSION

The repertoire of bird songs mainly in those Neotropical species is little described. This lack of knowledge is notable even in passerine species distributed in Argentina, such as *P. dumicola*. Following what was expected from the social behavior, *P. dumicola* showed great amplitude in its call repertoire. Adult males emitted at least 12 different calls that varied in structure and function. Calls were composed of a series of repeated notes and, in some cases multiple harmonics of dominant frequency (e.g. alarm). This study is the first that describes the complex repertoire of this bird species. Although this study did not cover the complete distribution range of this species, it provides a detailed description of the call repertoire with

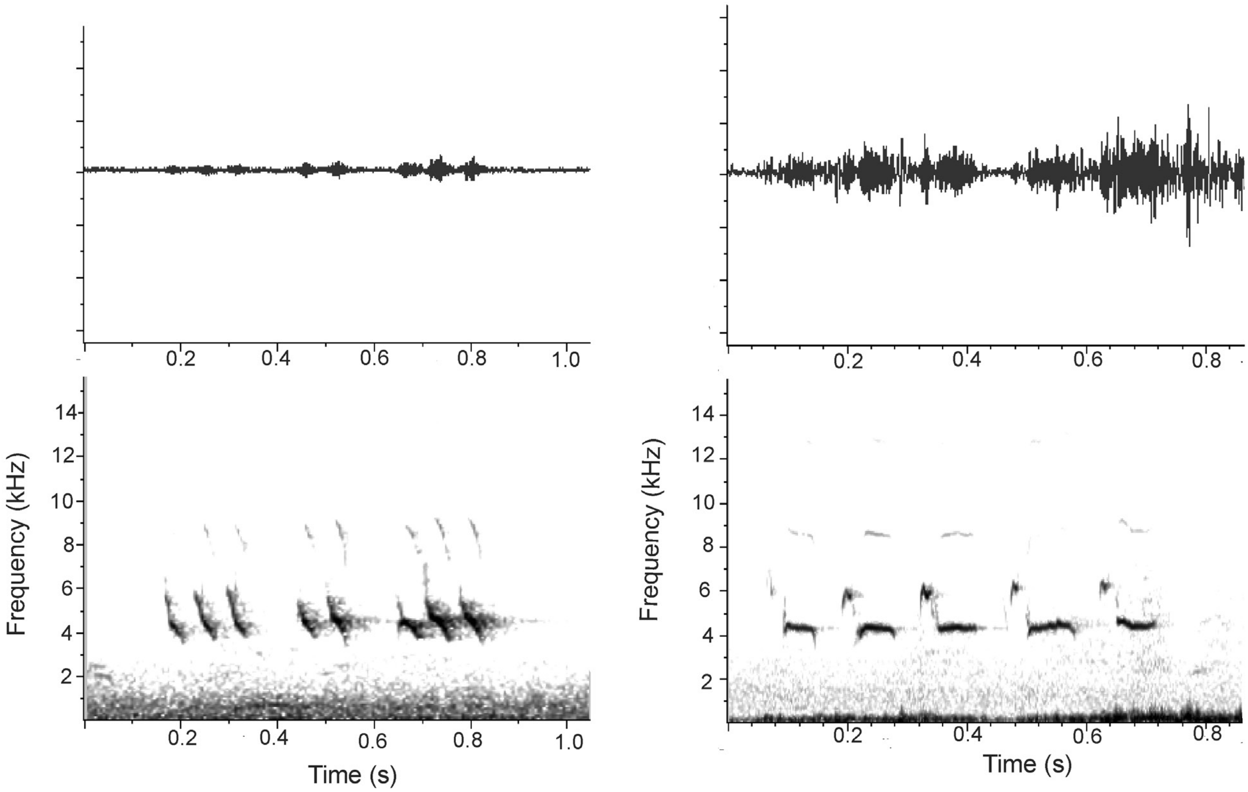

Figure 3. Oscillogram (upper part) and spectrogram (lower part) of unassigned call of *P. dumicola.*

a large sample size that can be useful in future comparative studies, like those related to call variation and complexity among bird species.

P. dumicola is considered a social species, with (family groups of up to 5-6 individuals, large territories, cooperative-breeding (Fraga & Salvador 2013). Agreeing with this, its call variety was similar to that observed in other groups of social birds that present a wide repertoire such as *Pomatostomus ruficeps* (Crane et al. 2016) and *Baeolophus bicolor* (Sieving et al. 2010). Unlike social species, non-social species such as *Upucerthia valdirostris* has vocal repertoires in which calls and songs are almost indistinguishable (Areta & Pearman 2013).

Thus, our results agreed with the hypothesis of social complexity (McComb & Semple 2005, Le Roux et al. 2009), showing that as association with conspecifics increases, communicative complexity and the potential to be used in mutual and more complex behavioral interactions also increases (Bradbury & Vehrencamp 2011). This communicative complexity found in *P. dumicola* suggests that vocal variation may be assigned to sociability differences that occur among different populations and it may be derived from learning deviations that occur over generations (Podos & Warren 2007).

Alarm calls

Call repertoire was composed of 50% of alarm calls emitted in the presence of possible predators of eggs and chicks - e.g. snakes, rodents, and other birds (Bradbury & Vehrencamp 1998). These calls are considered referential because they transmit encoded information about different environmental situations. Several studies show that different numbers of notes, harmonics, and bandwidths associated with the intensity of the threat are recorded among alarm calls in birds. Although intensity or frequency of the predator was not evaluated here, the number of notes is similar that those reported for *Poecile atricapilla* (i.e. 2 and 6 notes) when was stimulated by taxidermic mount of a *Falco mexicanus* (Baker & Becker 2002, Templeton et al. 2005). This similarity could imply that *P. dumicola* could undergo selection pressures similar to *P. atricapilla* against the potential risk of a specific predator.

Short-distance alert calls were the most recorded. These calls had high maximum and minimum frequencies, even greater than *Pomatostomus ruficeps,* a species that emits calls of high frequency (Crane et al. 2016). Short-distance alert calls were emitted when the male was approximately 15 meters away, that is, the distance at which this sound is perceived. For example, distress calls were longer than warning calls and generally, they were heard when individuals were captured and manipulated in mist nets. Then, this vocal signal likely contains information about the degree of threat that a situation represents. The results of the short distance alert of *P. dumicola* may be explained in terms of its subtle and sophisticated signaling systems because this species combines both referential and risk-based antipredator vocalization systems (Blumstein 1999, Seyfarth & Cheney 2003).

Danger calls can be associated with the “warning hypothesis” (Rohwer et al. 1976) which states that these types of calls can be altruistic when attempting to warn nearby kin of the presence of a predator. Coinciding with Caro (2005), this is a key antipredator strategy that has evolved in a wide range of species. Specific calls of individuals of *P. dumicola* were recorded in the presence of snakes as *Philodrya aestiva*. This is similar to those pointed out for *Cracticus tibicen* dorsalis, that emit and which is able to discriminate between alarms calls of different individuals associated with predatory stimuli (Silvestri et al. 2019). These calls allow individuals to escape against an imminent danger by either fleeing or undertaking appropriate defensive measures (Griesser 2013, Hollén & Radford 2009) Further research is needed to determine whether *P. dumicola* discriminates between individual alarm callers.

However, based on their social behavior, it is likely that *P. dumicola* can also shift their behavioral response according to the accuracy of social information (i.e., calls of different individuals and different human or natural threats) as documented in social species such as babblers (Flower et al. 2014) and weavers (Baigrie et al. 2014).

Anguish calls were directly associated with stress caused by the loss of chicks or couples and they had the primary purpose of alerting the couple, conspecifics, or hetero-specific individuals (Møller et al. 2011, Class & Brommer 2016). It was a strong and concise sound associated with predation events, such as has been determined in *Pomatostomus ruficeps* (Krams et al. 2014). This type of call has been recorded in other terrestrial vertebrates, such as on common frog *Leptodactylus chaquensis*, and although it presents different frequency values, they are also short-lived and strident sounds (Dorado Rodrigues et al. 2012). According to some authors, it is likely that adult males are familiar with their permanent social mates for weeks and months (Krams et al. 2006). Thus, the emission of anguish calls can be an altruistic act helping their fellow against the predator.

Contact calls

Contact calls occur as a response within a group, as it has been shown in dolphins (Janik & Slater 1998) and birds (Farnsworth 2005). In birds, contact calls are emitted during the feeding of chicks (Balsby & Bradbury 2009) and coordination activities (Jouventin & Aubin 2002). Contact calls are soft sounds easily identifiable, of broadband, and audible only at close range.

Contact calls between members of the *P. dumicola* couple (contact call to the female) were similar to that found in *Forpus passerinus* (Berg et al. 2011). These are high-frequency calls (5-6 kHz), with short duration and completely distinguishable from the rest of the calls. These contact-call characteristics possibly complicate the location of the sound source to predators (Marler 2004). Therefore, similarly to Berg et al. (2011) findings, mate recognition via contact calls in *P. dumicola* may be selectively advantageous during incubation because it reduces the potential costs associated with confusing contact calls of mates with those of non-mates.

Territorial call was recorded when a male of *P. dumicola* entered territories previously occupied by another conspecific male. Territorial calls were characterized by a high frequency (5.25 kHz) and several repeated notes (between 9 and 12). Although *Crotophaga ani* presented a lower mean frequency (1 kHz) in territorial calls (Grieves et al. 2015), they had frequency towards the end of the note and territorial calls were also recorded when a group or alone bird entered another group's territory. According to Crane et al. (2016), territorial calls could be used in dominance interactions in both breeding and roosting behaviors.

Incubation calls emitted by males *of P. dumicola* during incubation were short whistles of modulated frequency. Studies carried out with *Parus major* mention that this call can have an effect on predation because the issuing individual has fewer possibilities of becoming prey (Krams et al. 2006). Records on the vocal structure of incubation calls are scarce. It has been documented that *Passer domesticus,* which also has biparental nest construction, emits this call after placing feathers in the nest construction (García-Lopez de Hierro et al. 2013). Probably, the importance of this call is associated with its role in reproduction and parental care, including the nest construction by both members of the couple.

Long distance call of *P. dumicola* had approximately eight notes of modulated frequency, where the beginning of the tone has a lower frequency like in *P. ruficeps* repertoire (Crane et al. 2016). This type of call is common among other vertebrate groups (e.g. frogs, bats, apes, etc.) and can report spatial position (Class & Brommer 2016, Spillman et al. 2017) or increase feeding possibilities (Cortopassi & Bradbury 2006). Calls of modulated frequencies are not easily masked by environmental noise or other conspecific signals (Catchpole & Slater 2008).

In *P. dumicola* the long-distance call may be the first step toward recognizing individual identity or kinship as indicated by Crane et al. (2016). Further research must be done to test whether short-distance alert call is usually emitted before the long-distance call or if a territorial call is given before the call to a female. This will, allow extracting novel call sequences in the future, representing a new analogy between animal communication systems and human language (Hurford 2014).

Cataloging calls of bird species is key for understanding the complexity of bird vocalizations considering that informal or individual descriptions rarely assess vocal behavior correctly. The male's repertoire of *P. dumicola* provides important information to understand the link between ecology and behavior of this species. In this sense, the wide variety of calls such as those found in *P. dumicola* may allow birds to distinguish different environmental and ecological situations. The baseline information reported here is also key for future studies on the acoustic structure of passerines. Thus, these types of studies improve our understanding of adaptations of communication and provide valuable insights intothe ecological factors that drive the variation and evolution of animal signals.

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