Short Communication

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The complex distress call of *Ptychadena pumilio* (Boulenger, 1920) (Anura: Ptychadenidae)

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Abstract. We describe the previously unknown distress call of *Ptychadena pumilio*. The call is composed of three completely different kinds of notes. The composite note is the most complex and longest note. It starts with a long series of pulses modulated in amplitude, continues with a region of complex harmonic structure modulated in amplitude and frequency and ends with a short series of pulses. The short modulated note is the shortest note and the only one that lacks pulses. It consists of a single, short sound modulated in frequency and amplitude and with harmonic structure. The pulsed note is intermediate in length relative to the other two kinds of notes, and is the only one that lacks harmonics and frequency modulation. We hypothesize that the high diversity of notes involved in the distress call of *P. pumilio* and the complexity and variability of distress calls in other species may be the result of the adaptation to attempt to "tune" these calls to the auditory sensitiveness of different possible predators.

Key words. Amphibia, vocalisation, evolution.

During fieldwork in Senegal, the previously unknown distress call of *Ptychadena pumilio* (Boulenger, 1920) (Fig. 1) was recorded. This call is surprisingly complex and deserves a detailed description that may be useful in understanding the evolutionary origin and significance of distress calls in anurans. Calls were recorded on TDK SA60 cassettes using a Sony WM D6C tape recorder and a Sennheiser ME 80 directional microphone with K-3U power module. Calls were digitized at a sampling frequency of 44.1 KHz and 32-bit resolution with a Delta 66 digitizing board, and edited with Audacity 1.2.6 for MacOS X (Free Software Foundation Inc. 1991). Praat 4.5.02 for MacOS X (Boersma & Weenink 2006) software was used to obtain numerical information and to generate audiospectrograms and oscillograms. Frequency information was obtained through Fast Fourier Transformations (FFT) (width 1024 points). Two adult males (MNCN 44065–6; snout-vent-length 24.2 and 24.6 mm, respectively) and digitized calls (FonoZoo number: 6861) have been deposited in the amphibian collection and Fonoteca Zoológica, respectively, of the Museo Nacional de Ciencias Naturales, Madrid, Spain (MNCN). Terminology of call characteristics follows Hödl & Gollmann (1986) as modified by Padial et al. (2006).

Fig. 1. Adult male (one from MNCN 44065-6) of *Ptychadena pumilio* in life from Simenti, Niokolo Koba National Park, Senegal. Photo: J. Rodríguez-Osorio.

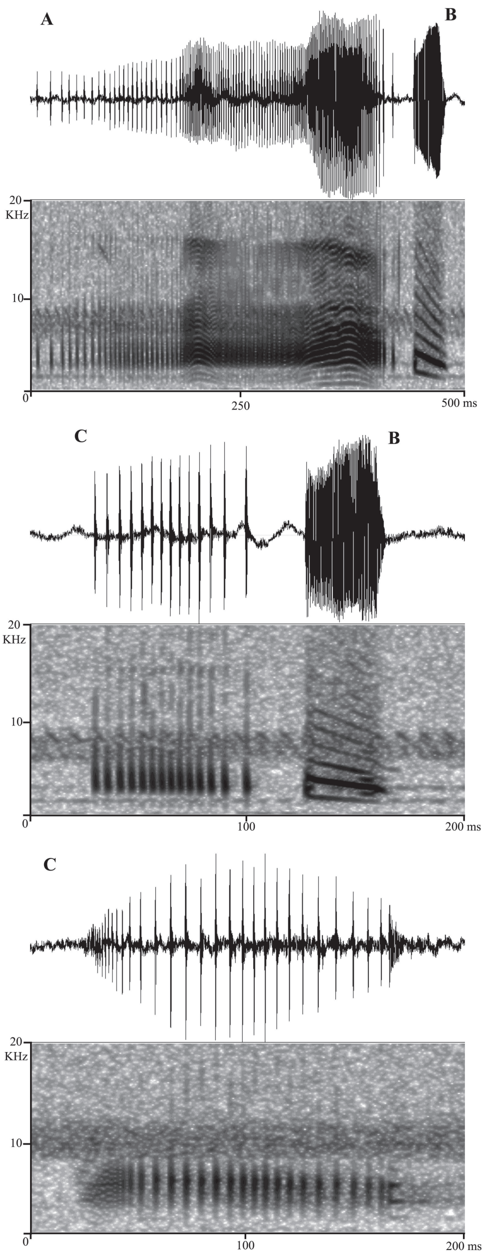

Fig. 2. Audiospectrograms and oscillograms of the distress calls of *Ptychadena pumilio* from Niokolo Koba National Park, Senegal: (A) Composite note; (B) Short modulated note; (C) Pulsed note.

Rödel (2000) provided a comprehensive account for *P. pumilio* including a description of its advertisement call, but not its distress call. We recorded distress calls of *P. pumilio* at Simenti, Niokolo Koba National Park, Senegal (13°01'40.7" N, 13°17'37.9" W), on the night of 10 April 2006 (air temperature 31°C). To record the distress calls, two specimens were held by their hind legs until they begun to vocalize (with the mouth closed or partially opened) when shaken slightly. Call length, call rate, dominant frequency, amplitude and number of harmonics changed with the intensity of shaking (Table 1). The distress call of *P. pumilio* is composed of three different kinds of notes (Fig. 2):

Composite note (Fig. 2A): this is the longest and most complex note. It starts with a long series of pulses modulated in amplitude, continues with a region of complex harmonic structure modulated in amplitude and frequency, and ends with a short series of pulses (Table 1). This note is usually followed by one or two short, frequency-modulated notes without pulses (*short modulated note*, see below). The amount and range of energy invested, the dominant frequency and the number of harmonics of the call reach the highest values in this kind of note. Most energy is invested after the third harmonic; indeed, dominant frequency might correspond to any harmonic up to the third.

Short modulated note (Fig. 2B): this is the shortest note and the only one that lacks pulses. It consists of a single, short sound modulated in frequency and amplitude, and with harmonic structure (Table 1). These notes were emitted after composite notes, or after one pulsed note (see below), or on its own when the specimen was less stimulated. Most of the energy of the call is distributed between 1400-6000 Hz into one to five dominant harmonics. The dominant frequency usually coincides with the second or third harmonic.

Pulsed note (Fig. 2C): this note is intermediate in length relative to the other two kinds

Tab. 1. Summary of quantitative parameters of the different notes of the distress calls of *Ptychadena pumilio*.

	call length (ms)	dominant frequency (Hz)	fundamental frequency (Hz)	intensity Range (Hz)	number of harmonics	dominant harmonics	pulses before harmonics	pulses after harmonics
				Composite note				
specimen 1 (n = 2)	139 409	4444 3626	1516 690	3993-8753 2827-7393	11 17	3-6 3-8	10 5	3 3
specimen 2 (n = 11)	378 (41-710)	3831 (2773-10915)	949 (497-1641)	3040-12414 (2446-13911)	18 (12-25)	3-25	18 (12-25)	8 (3-13)
				Short modulated note				
specimen 1 (n = 4)	151 (23-215)	3381 (2270-4538)	1037 (1079-2270)	2706-5329 (1904-6323)	6 (2-10)	1-5	0	-
specimen 2 (n = 16)	38 (924-46)	2988 (1594-3520)	1718 (1051-3321)	2011-4590 (1469-8821)	5 (3-9)	1-3	0	-
				Pulsed note				
specimen 1 (n = 1)	152	5590	5590	4500-6000	0	-	20	-
specimen 2 (n = 2)	74 84	3018 2925	3018 2926	2682-4479 2308-7055	0 0	- -	14 16	- -

of notes, and is the only one that lacks harmonics and frequency modulation. Amplitude can be modulated, with the highest amplitude reached in the middle of the call. The dominant frequency coincides with the fundamental, and is higher than in the other call types (Table 1).

The complexity of the distress call of *Ptychadena pumilio* evidences that a single specimen is able to emit completely different kinds of sounds within the same sound emission. In contrast, advertisement calls of amphibians are usually regular and constant and most likely evolve in a single direction under sexual selection (e.g. Blair 1956, Ryan 1980). On the other hand, distress calls in frogs are emitted under dangerous circumstances presumably to disturb or discourage predators (Hödl & Gollmann 1986, Leary & Razafindratsita 1998) and differ completely from advertisement calls of the corresponding species. Hence, the main evolutionary force acting upon distress calls should be natural selection (Laiolo et al. 2004). This may be supported by the fact that females and juveniles are able to emit distress calls (Sazima 1975, Duellman & Trueb 1986) and that, in contrast with advertisement calls, distress calls are very similar between different species of distant taxa (Duellman & Trueb 1986, Hödl & Gollmann 1986, Padial et al. 2006). Laiolo et al. (2004) provided evidence suggesting the transmission of information from prey to predator through distress calls. Nevertheless, amphibians are subject to predation by many different species of vertebrates and invertebrates (Duellman & Trueb 1986). Hence, we hypothesize that the high diversity of notes involved in the distress call of *P. pumilio* and the complexity and variability of distress calls in other species (Bosch et al. 1996, Martins & Haddad 1998, De Souza & Haddad 2003, Padial et al. 2006) may be the result of the adaptation to attempt to "tune" the distress calls to the auditory sensitiveness of different kinds of predators. Some birds are sensitive to specific stimuli associated with changes in frequency modulation and number of harmonics (e.g. Charrier et al. 2001), and bats show a behavioral response to constant frequencies in the sonic range of their frog prey (Ryan et al. 1983). Indeed, these are parameters that are constantly changed in distress calls (e.g. Padial et al. 2006, this study). Furthermore, predators of frogs may also have the ability to reverse the evaluation of the cues that signal preferred versus poisonous preys (Page & Ryan 2005). It would be interesting to test if the complexity of distress calls might be a result of natural selection favouring the flexibility of prey to vary cue signals interpretable by predators. To our knowledge, there is no experimental study on amphibians that attempts to address these questions. Moreover, there is no comparative phylogenetic study that attempts to study the pattern of evolution of distress calls in different taxa. Distress calls could have evolved quickly in anurans and been retained due to their putative efficacy in disturbing or discouraging predators, or could have evolved several times for the same or other reasons. If this kind of analysis were to be done, the results could be contrasted with the geographic patterns of diversity of putative predators, in order to identify any relationship that may illustrate the pattern of evolution of distress calls to specific predators. Nevertheless, all these initiatives may be impeded by the limited number of anuran distress calls described to date.

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