

1996). However, it is low compared to *A. jerboa*, where the upper frequency range extends up to 11 000 Hz (Matsui et al., 1993). The long call intervals of *I. beddomii* and the high frequency range of *T. rufescens* are conspicuous features among Indian ranids described so far.

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Advertisement calls of seven species of hyperoliid frogs, from Equatorial Guinea

Jaime Bosch¹, Ignacio De la Riva¹, Rafael Márquez^{1,2}

¹ Museo Nacional de Ciencias Naturales (CSIC); José Gutiérrez Abascal 2, 28006 Madrid, Spain

² Centro de Biologia Ambiental, Universidade de Lisboa, P-1700 Portugal

Corresponding author: Rafael Márquez; e-mail: rmarquez@mncn.csic.es

The comparison of anuran advertisement calls is a powerful tool for the determination of the taxonomic position of specimens collected in less explored areas. In Africa, anuran

faunas from the tropical rainforests are still poorly known. Most publications on anurans and their vocalizations are devoted to species from the forest belt of West Africa (i.e., Schiøtz, 1964, 1967). Many of those forest species were considered to have a broad African distribution, but further studies have demonstrated that, in some cases, they actually consist of two vicariant species, one living in West Africa and a second species occurring in central Africa. This often renders the species from the central African rainforest much less known than their occidental counterparts. Within the central African forest block lies the small country of Equatorial Guinea, which comprises a continental part, Río Muni, and some islands in the Gulf of Guinea, namely Bioko, Pagalu, Corisco and the Elobeyes. The anuran fauna of Río Muni includes a considerable array of species, which have only recently been described (De la Riva, 1994). However, its fauna remains among the least known even when compared to other countries in the area.

In this paper we contribute to the knowledge of the anuran fauna of Equatorial Guinea in particular, and central Africa in general, by providing a quantitative description of the calls and calling behavior of seven species in the family Hyperoliidae, some of which were previously undescribed quantitatively.

Recordings were obtained by the second author in 1993. Recording equipment included either a Sony WM D6C or a Sanyo M1120 tape recorder and a Sennheiser Me 80 directional microphone. We present a representative audiospectrogram and oscillogram for a selected 2.5 s recording segment for each species. A longer recording (10-90 s) was analyzed when available to generate numerical information (mean, *s*, range) on the spectral and temporal characteristics of the sounds. For each species calls from a single characteristic male were analyzed.

Recordings were processed with a digital signal analysis system based on an Apple Macintosh. The sounds were digitized and edited at a sampling frequency of 44.1 kHz and 16 bit resolution with Sound Tools hardware and software. Signalyze software was used to obtain numerical information and to generate audiospectrograms and oscillograms. Frequency information was obtained through fast Fourier transform (FFT) (width, 1024 points). The terminology used for the description of the advertisement calls follows Heyer et al. (1990). Unless specified, classification and nomenclature of the species follow Frost, 1985).

Eleven different call characteristics were recorded. The variables considered were: call duration, notes per call, note duration, number of pulses per note, pulse rate (pulses per second), pulse duration/pulse period (T/P), dominant frequency, other frequencies with substantial energy, change in dominant frequency (dominant frequency at the end of the note minus dominant frequency at the beginning of the note), frequency range (width of dominant frequency band at maximum amplitude), notes per minute (within call), and calls per minute. Collected individuals were deposited in the Centro de Estudios Tropicales, Sevilla, Spain. Unless specified, recordings were obtained at different sites of Monte Alén National Park, a protected area in the center of Río Muni. The area is mountainous and

Table 1. Numerical characteristics of the advertisement calls. Mean, standard deviation (in parenthesis) and range (in brackets). n = number of calls or notes of a single male.

Species	Air temperature (°C)	n	Call duration (ms)	Notes per call	Note duration (ms)	Pulses/ note	Pulses/ second	T/P
<i>Arixalus brevipalmatus</i> Note A	23	2	832 (87) [741, 915]	1	166 (32) [143, 188]	20 (3.5) [18, 23]	123 (2) [122, 125]	0.605 (0.67) [0.557, 0.653]
<i>Arixalus brevipalmatus</i> Note B	23	13	-	5 (1) [4-5]	39 (14) [22, 72]	5 (2) [4, 9]	141 (20) [117, 179]	0.589 (0.14) [0.284, 0.756]
<i>Arixalus paradoxalis</i>	22	12	493 (146) [350, 731]	3 (1) [3, 5]	40 (13) [28, 77]	8 (1.5) [6, 10]	225 (32) [169, 261]	0.755 (0.118) [0.578, 0.885]
<i>Alexeteron obsstetricans</i>	20	3	22 (6) [16, 28]	1	22 (6) [16, 28]	8 (1) [6, 9]	361 (71) [288, 431]	0.195 (0.31) [0.167, 0.227]
<i>Hyperolius ocellatus</i>	19	29	169 (20) [155, 213]	4 (0) [4, 5]	169 (20) [155, 213]	-	-	-
<i>Hyperolius tuberculatus</i>	19	13	1026 (508) [558, 1999]	12 (7) [7, 22]	20 (7) [10, 38]	-	-	-
<i>Leptopelis aubryi</i>	18	4	43 (8) [31, 50]	1	42 (8) [31, 50]	13 (2) [11, 14]	281 (31) [251, 312]	0.887 (0.03) [0.853, 0.926]
<i>Phlyctimantis leonardi</i> Note A	24	14	164 (35) [92, 197]	1	75 (12) [58, 94]	14 (1) [12, 15]	187 (20) [149, 209]	0.715 (0.129) [0.566, 0.914]
<i>Phlyctimantis leonardi</i> Note B	24	27	-	2 (1) [0, 4]	8 (7) [4, 40]	-	-	-

Table 1. (Continued)

Species	Dominant frequency (Hz)	Other frequencies (Hz)	Change in frequency (Hz)	Frequency range (Hz)	Notes/minute	Calls/minute
<i>Afrivalus brevipalmatus</i> Note A	3463 (271) [3271, 3655]	–	283 (57) [242, 323]	1646 (100) [1575, 1716]	289 (43) [259, 320]	–
<i>Afrivalus brevipalmatus</i> Note B	3642 (69) [3554, 3776]	–	–3 (79) [–161, 101]	1209 (219) [909, 1676]	401 (144) [287, 705]	–
<i>Afrivalus paradorsalis</i>	2894 (86) [2786, 3009]	–	126 (277) [–141, 949]	1070 (289) [767, 1636]	347 (39) [318, 439]	25 (6) [20, 29]
<i>Alexteroon obstetricans</i>	3062 (12) [3049, 3069]	6037 (101) 5936-6138	20 (40) [–20, 61]	828 (105) [707, 888]	17 (1) [16, 18]	17 (1) [16, 18]
<i>Hyperolius ocellatus</i>	3954 (192) [3026, 4079]	–	–	628 (99) [464, 909]	1201 (69) [1029, 1277]	20 (4) [15, 24]
<i>Hyperolius tuberculatus</i>	3228 (53) [3110, 3311]	6448 (98) 6239-6623	–22 (99) [–262, 101]	510 (103) [323, 686]	683 (66) [535, 855]	34 (9) [22, 50]
<i>Leptopelis aubryi</i>	2049 (461) [1454, 2423]	–	162 (225) [–40, 404]	1540 (321) [1353, 2019]	19 (8) [12, 28]	19 (8) [13, 28]
<i>Phlycmyantis leonardi</i> Note A	2145 (305) [1413, 2484]	–	1269 (192) [868, 1575]	1209 (171) [787, 1373]	593 (99) [480, 755]	110 (75) [30, 256]
<i>Phlycmyantis leonardi</i> Note B	2471 (140) [2322, 2645]	–	–	691 (69) [585, 767]	1654 (327) [1210, 2429]	–

mostly covered with undisturbed rainforest. The study period comprised May to December 1993. The numerical parameters of the calls are shown in table 1.

Afrixalus brevipalmatus (Ahl) was common in the study area. Males called throughout the period of study at night, among the grass and other low vegetation (less than 1.5 m high), in open or disturbed areas, ponds, and overflowing streams, or areas of streams with calm waters. Recorded specimens were at a pond at the roadside. They were often heard with *Afrixalus paradorsalis* and *Hyperolius pardalis*. The call includes two notes (fig. 1A): the first one (note A) is a longer trill which is always included in the call. The dominant frequency of this note is high and increases (3.5-4 kHz). Note A is followed by four or five shorter trills (note B), higher in intensity. Both notes are pulsed, note A being composed of 18-23 pulses and note B of 4-9 pulses. All the B notes are similar except for slight differences in duration corresponding to different numbers of pulses. The power of the second note is concentrated in the 3.5-3.7 kHz range. Schiøtz (1999) provided a thorough discussion on the complicated and unsettled taxonomy of the *Afrixalus fulvovittatus* complex, which presents two types of morphologies and dorsal patterns, A and B. The specimens from Monte Alén [reported by De la Riva (1994) as *A. fulvovittatus*] belong to the type B. The proper name for the forest species of the type B from Cameroun southwards is *A. brevipalmatus* (Schiøtz, 1999; pers. com.). To the best of our knowledge, no description of the call of this species has been published.

Afrixalus paradorsalis Perret. This species was moderately common in the area. Individuals were recorded at a stream overflow near the Niegong-Evinayong road. Males called at night throughout the study period, from low vegetation (less than 1.5 m high), often together with *Afrixalus brevipalmatus*. The call is a sequence of three to five identical short pulsed notes with power in the 2.8-3 kHz range (fig. 1B). The total duration of the call is variable (range 350-730 ms). The call was repeated sporadically at irregular intervals. This species occurs in central Africa from Nigeria to Gabon (Schiøtz, 1999). Schiøtz (1967, 1999) described the call of *A. paradorsalis* (cited as *A. congicus paradorsalis* in Schiøtz, 1967) from Osomba (Nigeria). The overall structure of the call is similar to that reported by us, a sequence of short pulsed notes, with dominant frequency centered about 2.8-3 kHz. Schiøtz (1967, 1999) reports though that the call was composed typically of two notes and occasionally three, while we found the notes to be emitted in groups of three to five notes.

Alexteroon obstetricans (Ahl) is an uncommon species in the area. The recorded individual called on September 25, at night, perched in the vegetation more than 2 m above ground, near the Bilene river, in primary forest. Another frog species calling concomitantly nearby was *Nyctibates corrugatus*. The call is extremely short, pulsed, with most energy concentrated around 3 kHz, although some energy is present in the second harmonic (fig. 1C). The call is amplitude-modulated (not reaching 100%) and it is emitted at relatively long intervals (calling rate 15.7-17.8 calls/minute). Schiøtz (1999, p. 84) provides an audiospectrogram of the call of an undetermined locality in Cameroun, and describes it briefly as being "a metallic "toc", repeated 5-6 times". The frequency and duration of

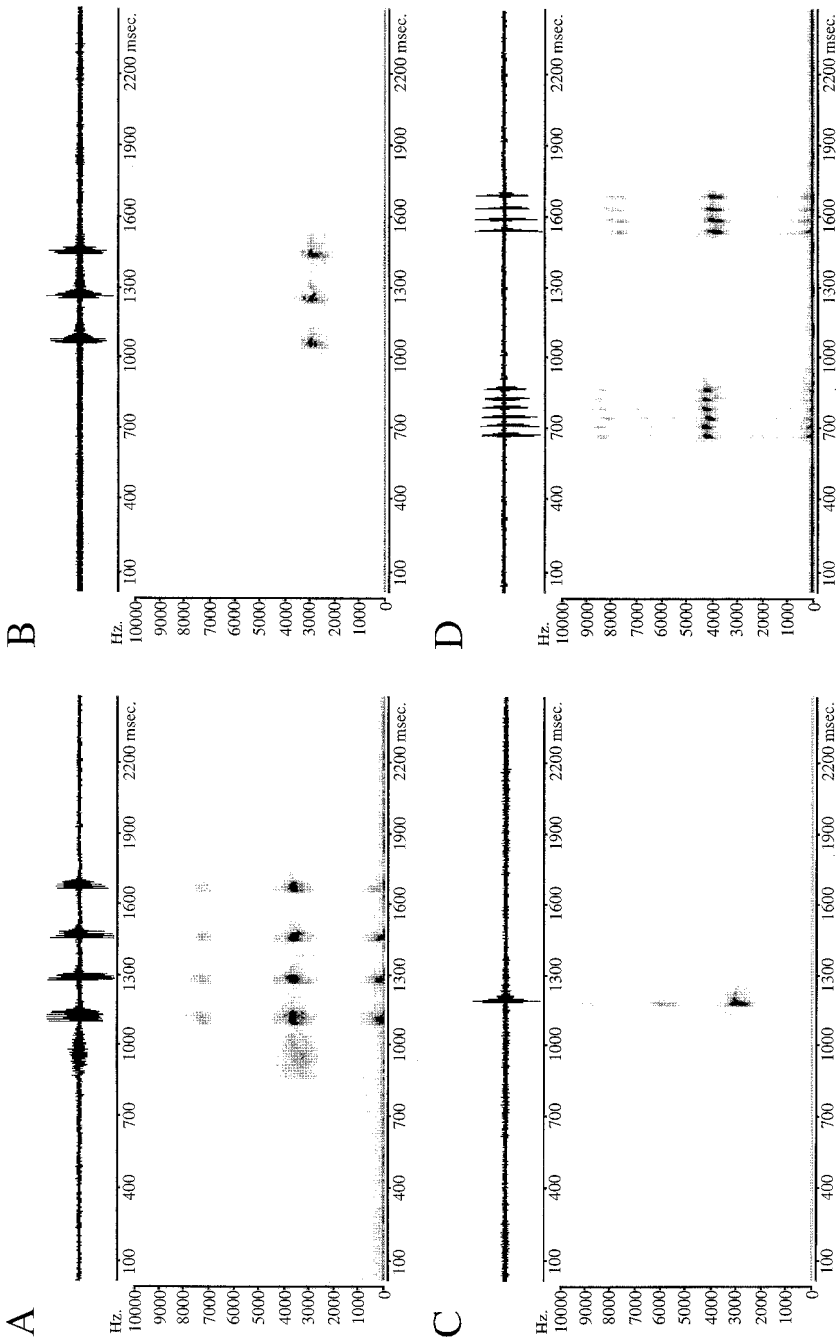


Figure 1. Characteristic audiospectrogram and oscillogram of an advertisement call of (A) *Arixalus brevipalmatus* note A followed by four B notes, (B) *Arixalus paradoxalis*, (C) *Alexteroon obterricans*, (D) *Hyperolius ocellatus*, two calls emitted by the same male: one with six notes and one with four notes.

the call represented in Schiøtz (1999) coincides roughly with that of our recordings but no further quantitative information is provided.

Hyperolius ocellatus Günther was moderately common in the Park. Males called at night throughout the study period. They perched on vegetation (bushes, small trees, ferns) surrounding streams both in primary and secondary forest. Other species calling concomitantly were *Afrixalus brevipalmatus* and *Hyperolius tuberculatus*. The call is a brief sequence of four or five high frequency notes emitted at regular intervals (fig. 1D). The energy is concentrated between three and four kHz. Occasionally two isolated notes have been heard (not included in the statistics in table 1). This is a widespread species in Central Africa (Perret, 1975; Largen and Dowsett-Lemaire, 1991). Schiøtz (1999) provides an audiospectrogram of an advertisement call of *H. ocellatus* from Osomba (Nigeria) which is similar to our fig. 1D. He only provides an additional brief comment about its frequency “an indistinct frequency-intensity maximum at about 3800-4000 cps” which does not disagree with our description.

Hyperolius tuberculatus (Mocquard) is a moderately common species in the area studied, and seems to be more abundant during the dry seasons. Males called at night, perched on the branches of bushes and riparian vegetation in disturbed areas, but they were seen also in ponds in open areas with bushy vegetation outside the park, at the grassy coastal belt near Bome. Individuals were recorded at a stream crossing the road near Moka, in Monte Alén. The call is a sequence of 7-22 high frequency short notes. Most calls have seven to ten notes (fig. 2A). Largen and Dowsett-Lemaire (1991) describe the call of the species in the Republic of Congo as a rather quiet “chink-chink-chink.” Although this description somewhat coincides with our recordings from Monte Alén, it is too limited to allow for quantitative comparisons. Schiøtz (1999) provided an audiospectrogram of a call of *H. tuberculatus* from Binguela (Cameroun) recorded by Amiet. He also stated that the individuals from this area differed “in many respects” from the sample treated by Largen & Dowsett-Lemaire (1991). The call shown in the audiospectrogram in Schiøtz (1999) has a note repetition rate of 12-13 notes/sec, a total of 21 notes per call, and the dominant frequency is approximately at two kHz. While the note repetition rate is similar to that found in our recordings, and the number of notes per call is also within the range found by us, the frequency found in our recordings from Monte Alén is substantially higher than that depicted in the audiospectrogram in Schiøtz (1999) which is about 2 kHz. This difference may just reflect a marked difference in size in the specimens or could be relevant taxonomically.

Leptopelis aubryi (Duméril) was moderately abundant in the park. Males called at night during September and October, from thick bushes on the sides of the road, at 1-1.5 m above the ground, occasionally near ponds. The advertisement call is a very sharp, rasping sound (fig. 2B). It is extremely brief (31.3-50 ms) and its energy is spread over a wide frequency band from two to four kHz and beyond. The call is amplitude-modulated, and it is emitted at relatively long, irregular intervals. Amiet and Schiøtz (1974) and Schiøtz (1999) describe two different vocalizations of *L. aubryi* from NíKongsamba (Cameroun).

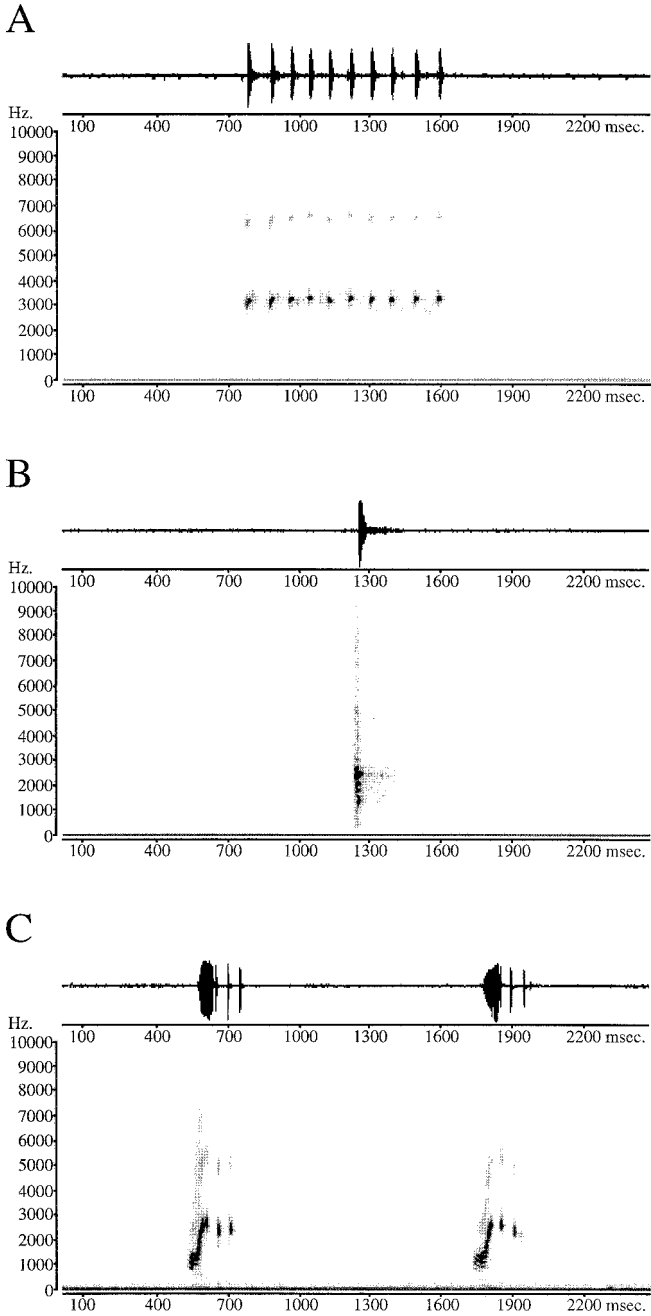


Figure 2. Characteristic audiospectrogram and oscillogram of an advertisement call of (A) *Hyperolius tuberculatus*, advertisement call with ten notes, (B) *Leptopelis aubryi*, (C) *Phlyctymantis leonardi*, two ABB calls from the same male.

The call identified by them as the mating call is similar to the call recorded by us, both in duration and in frequency. The second call type described in Cameroun (a fast sequence of groups of 2-3 clicks) was not recorded or heard in Equatorial Guinea.

Phlyctymantis leonardi (Boulenger) is a rare species in Monte Alén National Park, where only one individual was seen in a pond by the road, near Ayene. Contrarily, a notable aggregation of males was observed and recorded on November 8, calling from the ground around a pond near Bome, a locality outside the park, on the grassy prairies along the coast of Río Muni. The only other species observed concomitantly was *Hyperolius tuberculatus*. The call is extremely loud and is composed of two notes, a “woah” (note A) followed by a clicking sound or note B (fig. 2C). Note A can be emitted in isolation or followed by 1-4 notes B. Note A is a sequence of 12-15 pulses repeated at irregular intervals. Note A is short with a long raise time peaking at the 11th pulse, and a faster fall time, followed by (1-4) isolated pulses emitted at relatively longer intervals (27.9 ms). The first pulses of the call have a much lower dominant frequency (about one kHz) than the last three or four pulses which reach 2.4 kHz. The resulting sound has therefore a marked upwards frequency change. An even higher dominant frequency is found in the B notes emitted after the A note which are extremely short. When more than one B notes are emitted it appears as if the dominant frequency and the intensity of consecutive notes decreased. The vocal sac of this species is remarkable as that of the rest of the Kassiniinae: it consists of a main, subgular chamber, with a lateroventral slit on each side. This slit is the opening to an invaginated, internal projection of the gular skin. Note A is produced using only the main sac, which is inflated for this purpose. When the air pressure within it rises, the two projections are evaginated and they vibrate, producing note B. The choruses of these frogs are extremely cacophonous and loud.

The recording obtained in Monte Alén (not shown in the figures) only included note A. The differences between the calls heard at Monte Alén and those from near Bome are probably due to the very different social context in which these recordings were obtained (a single, isolated male in Monte Alén versus a large chorus in Bome) although given the differences in frequency changes observed, we cannot reject the possibility that the individual recorded in Monte Alén may belong to a different taxon. Schiøtz (1967) described the “reproductive call” of *P. leonardi* from a site W of Danané (Côte d’Ivoire). The call described is 0.1 s long and shows upwards frequency change (from 0.9 to 2.9 kHz). This call is markedly different both in temporal and in spectral characteristics to the call recorded by us in Bome, supporting Schiøtz’s more recent re-assessment, that considers that the species occurring in West Africa is *P. boulengeri* (Schiøtz, 1999). We can therefore suggest that the individuals recorded in Côte d’Ivoire and in Equatorial Guinea do not belong to the same species. On the other hand, the description of the recordings obtained by Largen and Dowsett-Lemaire (1991) in Tchissanga (Republic of Congo) suggest that the vocalizations are similar to those recorded in Bome and Monte Alén.

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Home range and shelter use in *Salamandra lanzai* (Caudata, Salamandridae)

Alexandre Ribéron, Claude Miaud

Université de Savoie, UMR CNRS 5553, Laboratoire de Biologie des Populations d'Altitude, 73 376 Le Bourget du Lac, France

The spatial organization of salamanders results from environmental conditions (Ovaska, 1987; 1988; Mathis, 1990), the presence of congeners (Jaeger et al., 1995; Marvin, 1998a; Nishikawa, 1990), and of other species (Anthony et al., 1997; Marvin, 1998b; Nishikawa, 1990; Ovaska, 1993). The size and shape of home ranges are the basis for understanding spatial organization, yet the patterns of movements and home range definitions are often hardly discussed (Kenward, 1987; Rose, 1982; White and Garrot, 1990). Home range can be defined as the area over which an animal normally travels in pursuit of its routine