

MATING CALLS OF THREE SPECIES OF ANURANS FROM BORNEO

M. J. SANCHEZ-HERRAIZ¹, R. MARQUEZ², L. J. BARBADILLO³ AND J. BOSCH²

¹ Dept. Biodiversidad y Biología Evolutiva, Museo Nacional de Ciencias Naturales, C.S.I.C., J. Gutiérrez Abascal 2, Madrid 28006, Spain

² Dept. Ecología Evolutiva, Museo Nacional de Ciencias Naturales, C.S.I.C., J. Gutiérrez Abascal 2, Madrid 28006, Spain

³ Dept. Biología, Universidad Autónoma de Madrid, Cantoblanco, 28049 Madrid, Spain

Mating calls of three anuran species from Borneo, *Rana glandulosa*, *R. signata* and *Polypedates leucomystax* were analysed. The audiospectrograms obtained were compared with previously published descriptions of the calls of these species in different geographic areas. The comparisons revealed a high level of heterogeneity of the calls within the range of *R. signata* and *P. leucomystax*. The possible taxonomic implications of these findings are also discussed. The first description of the mating call of *R. glandulosa* is presented.

INTRODUCTION

The anuran fauna of SE Asia, and particularly that of Borneo, holds one of the highest levels of diversity found in the world (Frost, 1985; Groombridge, 1992). In spite of this phenomenon, knowledge about the biology of most species is extremely limited, especially if compared with the available information about the amphibian fauna from other neotropical areas. Recent publications have contributed significantly to the advance of the knowledge of anuran taxonomy of SE Asia (e.g., Inger, 1989, Inger & Stuebing, 1991). However, it is difficult to determine the actual number of species of amphibians present in many areas, including Borneo (Inger & Stuebing, 1989). Most published taxonomic published studies are based on morphological characters, while only a few take into account aspects of natural history and ecology of the species (e.g. Alcalá & Brown, 1956; Matsui, 1979); and even fewer consider genetic aspects for taxonomic comparisons (e.g. Matsui *et al.*, 1986; Kuramoto & Yong, 1992). The importance of advertisement calls as mechanisms for pre-mating isolation have been emphasized for a number of species of the temperate zone (Littlejohn, 1981, 1988; Gerhardt, 1988, 1991). The modern techniques of sound analysis provide an efficient quantification of the temporal and spectral components of call parameters, which allows quantitative comparisons at different levels (Duellman & Pyles, 1983; Márquez *et al.*, 1993). As for the Asian anuran fauna, some studies have also addressed the importance of the advertisement calls as a relevant characteristic to define the taxonomic status of different taxa (Alcalá *et al.*, 1986, Brzoska *et al.*, 1986; Matsui *et al.*, 1986).

The present study contributes to the knowledge of three anuran species from Borneo, describes their mating calls and provides information about calling behaviour. Whenever possible, the results of the analysis of the recordings are compared with previously

published descriptions of the same species, in an effort to determine the homogeneity of the calls within the ranges of distribution of the species. These comparisons may suggest lines for future taxonomic research.

MATERIAL AND METHODS

Specimens were recorded in Borneo in July and August 1991. Recordings were obtained in Gunung Mulu National Park (4° N 115°E) and in Bako National Park (2°N 110°E), in the region of Sarawak, Borneo, Malaysia. Recording equipment included a portable tape recorder Sony WM D3 and a directional microphone ATR 55 Telemike. Recordings were edited and analysed with an Apple Macintosh-based digital sound analysis system. Sounds were digitised at a sampling rate of 44.1 KHz and with 16 - bit resolution, with Sound Tools hardware (Digidesign 1360 Willow Rd, Menlo Park, CA 94025 U.S.A.). Numerical parameters of the spectral and temporal components, as well as audiospectrograms and oscillograms, were obtained with Signalyze software (Infosignal Inc. CP 73, CH-1015 Lausanne, Switzerland). Spectral components were based on fast Fourier transform (FFT) with window width of 1024 points. Seven call characteristics were measured: call duration, number of pulses or pulse groups per call (*sensu* Schneider & Sinsch, 1992), pulse rate (pulses per second), fundamental frequency, dominant frequency, other emphasized frequencies, and calls per minute.

Recorded specimens were identified visually *in situ*, based on their external morphology (Inger, 1966). Photographs were taken in order to confirm subsequently the initial identification. The photographic material was deposited in the photographic archive of the Museo Nacional de Ciencias Naturales de Madrid (Archive numbers: 7960-7966). Recordings were obtained at a temperature range of 22-26°C in Bako, and 20-24°C in Gunung Mulu. Recorded specimens were not collected: in agreement with the laws of the national

TABLE 1. Summary of numerical parameters of the advertisement calls. For each value, the mean, standard deviation (in parentheses) and range are shown. * in *R. signata* the values shown represent no. of pulse groups and pulse groups/sec.

	<i>Rana glandulosa</i>	<i>Rana signata</i>	<i>Polypedates leucomystax</i>
Number of individuals	1	1	3
Number of calls/individual	19	3	1.3-5
Duration (ms)	1502.2 (176.3) 1278 - 1802.8	620.7 (5.5) 614.3 - 624.4	143.5 (19.3) 130.5 - 165.7
Number of pulses	10.1 (1.1) 9 - 12	9 (0)* 9 - 9	13.4 (1.2) 11.3 - 15
Pulses/second	6.7 (0.2) 6.3 - 7	14.5 (0.1)* 14.4 - 14.7	94.0 (11.9) 84.3 - 107.3
Calls/minute	20.0 (1.2) 18.2 - 21.6	1.3 (0.8) 0.8 - 1.9	3.7 (0.6) 3.3 - 4.2
Fundamental frequency (Hz)	824.7 (19.5) 787.5 - 868.2	1130.8 (20.2) 1110.6 - 1151	2623.7 (273.3) 2398.9 - 2927.9
Dominant frequency (Hz)	2439.0 (63.7) 2281.7 - 2564.4	2402.9 (20.2) 2382.7 - 2423.1	2623.7 (273.3) 2398.9 - 2927.9
Other emphasized frequency (Hz)	1649.4 (38.7) 1575.0 - 1736.5		
	3286.0 (136.6) 2907.7 - 3392.3		
	5080.0 (337.1) 4866.3 - 6138.5		

parks where the recordings were obtained, they were freed in their capture sites immediately after recording and identification.

RESULTS AND DISCUSSION

Table 1 shows the summary of the numerical parameters measured from the recordings.

Rana (Pulchrana) glandulosa Boulenger, 1882.

The known geographic range of this species includes Thailand, peninsular Malaysia, and Sumatra and Borneo in the Sunda Archipelago (Inger, 1966). Although Inger & Stuebing (1989) reported that this frog occurs in flooded areas near the coast, our specimens were recorded in Gunung Mulu (Deer cave area, 4°N 114° 7'E) in a primary forest located more than 80 km away from the nearest coast. Males were widely dispersed. They were isolated, calling either from the ground or perched in low vegetation about 20-80 cm above ground. No choruses were found. The call of this species (Fig. 1A) consists of a loud and extremely long note (mean duration, 1502.2 ms) with 9-12 pulses. Its mean dominant frequency is 2440 Hz, and three additional harmonics (1650 Hz, 3286 Hz and 5080 Hz) are

other emphasized frequencies. The first harmonic, or fundamental frequency (825 Hz), is not emphasized. The call is repeated at a fast rate (about 20 calls per minute). To the best of our knowledge no previous publication of the call of this species is available for comparison.

Rana (Pulchrana) signata (Günther, 1872).

This species is known to occur in Thailand, Peninsular Malaysia, Sumatra, Borneo and Philippines (Frost, 1985) and is usually associated with medium-sized streams (Inger, 1966). Our recordings were obtained in a primary forest in the vicinity of Melinau Camp, in Gunung Mulu National Park (4° 3'N 114° 9'E). Males called in isolation with several metres between individuals and no choruses were observed. Most calling males were found on the ground along a stream bank. Only a few individuals were seen calling while perched up to 150 cm on the riparian vegetation.

The call has a mean duration of 620.7 ms. It is composed of a sequence of nine, evenly spaced, pulse groups repeated at regular intervals, with decreasing intensity and duration (average pulse group duration 35 ms, mean number of pulses per pulse group 7.7)

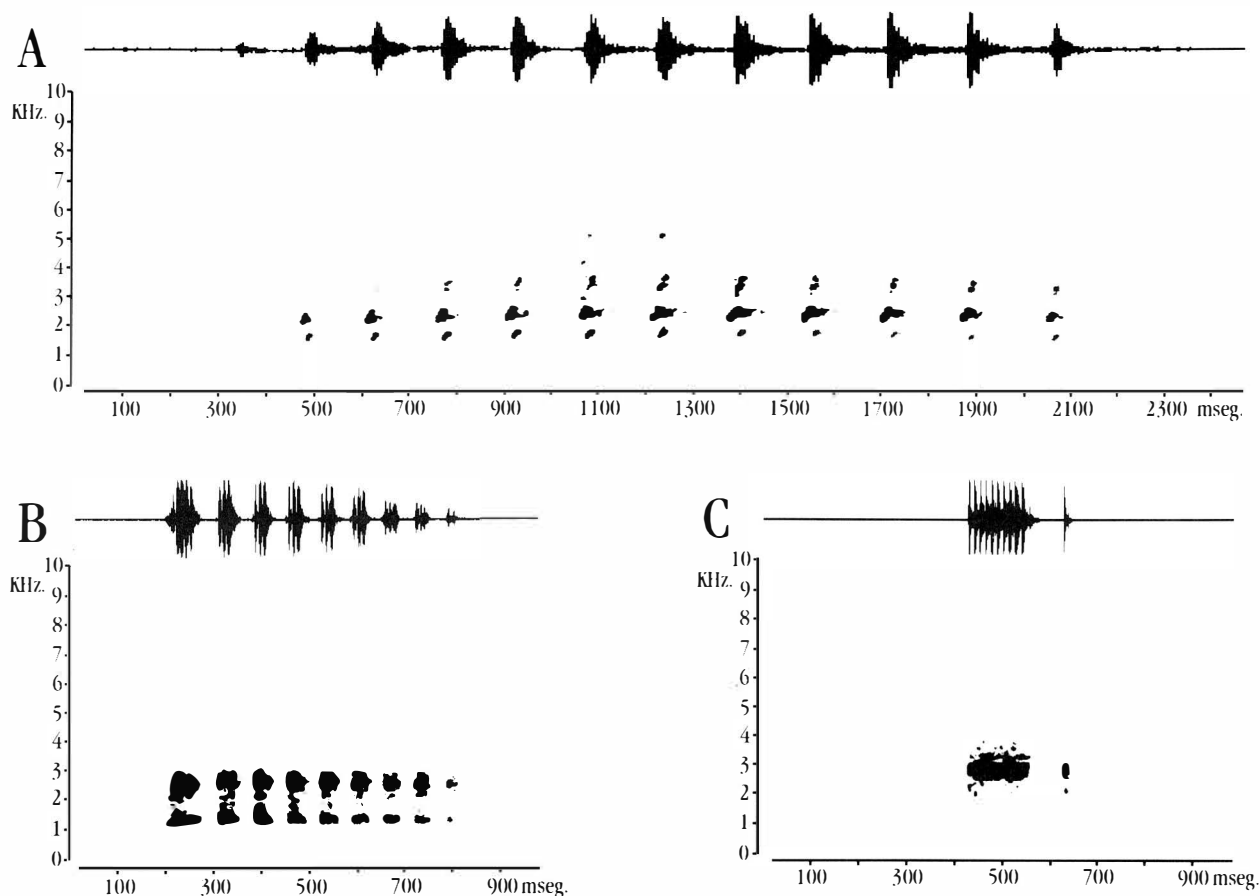


FIG 1. Audiospectrograms and oscillograms of a characteristic advertisement call of each species. A, *Rana glandulosa*; B, *Rana signata*; C, *Polypedates leucomystax*.

(Fig 1B). The mean dominant frequency is 2402.9 Hz while the average fundamental frequency is 1130.8 Hz. Alcalá *et al.* (1986) described the mating calls of individuals from Malinao, in the vicinity of Puerto Princes (Palawan Island, Philippines, 10°N 119°E). These individuals were identified by Inger (1954), as belonging to the subspecies *R. s. moellendorffi* Boettger. The calls of the Philippine specimens do not coincide with our recordings either in temporal or in spectral features. Alcalá *et al.* (1986) described a complex call with distinct note types: some initial tuned notes (tuned, *sensu* Heyer *et al.*, 1992) that do not resemble any of the sounds obtained in our recordings, and some final notes with a complex spectral structure that are somewhat more similar to the notes described by us, but have different emphasized frequencies (dominant frequency 1350 Hz, and power in the second harmonic at 2800 Hz). The differences in the mating calls found between our recordings for the Sarawak individuals and the results of Alcalá *et al.* (1986) from Malinao, are substantial enough to suggest that further studies on the differentiation of these populations may prove fruitful.

Polypedates leucomystax (Gravenhorst, 1829).

This taxon is considered to be a generalist species (Inger, 1966), having a vast distribution, ranging from Nepal, through SE Asia and continental China, up to Taiwan (Inger, 1966; Dubois 1976). The species has been also introduced in the Ryukyu archipelago (Matsui *et al.*, 1986). The individuals recorded were found calling near human quarters in the Bako National Park (Sarawak, 1° 7' N 110° 4' E). Males aggregated and formed choruses perched on the vegetation around ponds and flooded areas at variable heights (from a few centimetres to several meters above ground). The mating call is composed of a single pulsed note (10-16 pulses), relatively short (mean duration 143.5 ms), and with a mean dominant frequency of 2623.7 Hz. This note may be followed by an isolated supernumerary pulse (duration 4.3 ms) which has a similar dominant frequency (Fig. 1C). Other call types obtained in our recordings were shorter (40.55 ms duration), lower in intensity, composed of only three to five pulses, and with a dominant frequency slightly lower than that of the mating call (2380 Hz). These calls were not included in Fig. 1., since their intensity was comparatively

very low and the recording level was not adequate for a complete description. Heyer (1971) described the calls of *Polypedates leucomystax* from Sakaerat, Thailand. He described two note-types: the longer note (230-380 ms) showed a dominant frequency between 2500 and 2600 Hz, resembling our recordings from Borneo. However, other call characteristics differ. Thus, the spectral structure of the recordings from Thailand (300-2600 Hz) and the temporal structure of such calls (4-5 pulses) are clearly different from our recordings. On the other hand, the shorter note of the specimens from Thailand was described as being 120-250 ms in duration, and with 2-4 pulses. Such notes do not occur in our recordings, although perhaps the pulse structure resembles our supernumerary pulses. Nevertheless, the differences between the calls from Thailand and ours are substantial.

Matsui (1982) described the mating calls of *Polypedates leucomystax* from Ranau (Sabah, Malaysia). His description of the primary mating call is similar to our results, both in temporal features (duration 130 ms, 12.8 pulses/call) and spectral structure (dominant frequency 2488 Hz). The recordings of Matsui (1982) seem to show some emphasized harmonics that do not appear in our analyses; but differences in recording equipment or in recording or analysis techniques may account for this lack of agreement. Matsui (1982) also described a type of vocalization that he termed "after call", composed of tonal (i.e. well tuned) notes of variable duration. We did not record any of those call types. However, there is substantial agreement between the description of the main call in Matsui (1982) and our recordings. On the other hand, Kuramoto (1986) described the calls of *Polypedates leucomystax* from three sites in Taiwan. The calls of the Taiwanese individuals are extremely brief pulses with complex spectral structure (500-3300 Hz), emitted in groups of one to five pulses forming calls that lasted from 30 ms (one pulse) up to 581 ms (five pulses emitted separately). This call type does not resemble our recordings, but shows some similarities with the recordings described for specimens from Thailand (Heyer, 1971). Brzoska *et al.* (1986) described in detail the calls of *P. leucomystax leucomystax* Boie (subspecific status after Inger, 1966) in Negros, Philippines (9°N 123°E). They described three call types, although only one of them was considered to be an advertisement call. This call is slightly longer than those obtained by us (average duration 192 ms), and is composed of a similar number of pulses to the calls shown in our recordings (average 16.2 pulses/call). The fundamental frequency of some of the Philippine calls (Figs 3a, and 3b, in Brzoska *et al.* 1986) also appear to be similar to our recordings. Brzoska *et al.* (1986) also described some shorter notes which appear to coincide with our lower-intensity notes. Therefore, the similarity in advertisement call is further supported by the partial concordance in acoustic repertoire. In summary, the advertisement calls of *P. leucomystax* from

Borneo and the Philippines appear to be similar; while those of Taiwan and Thailand, though not identical, show a characteristic pulsed structure which could suggest a more recent common origin. This call pattern is also shared by the rest of the racophorid frogs from Taiwan (Kuramoto, 1986). Our results are in agreement with the conclusions of Matsui *et al.* (1986) who consider that the Taiwanese specimens of *Polypedates* are *P. megacephalus*, a distinct species from the Bornean population. Our bibliographical research on the published audiospectrograms of the mating calls of the sister species in the *Polypedates leucomystax* complex (*sensu* Inger, 1966), (Matsui, 1979) shows a high degree of variability in acoustical characteristics. This result supports the conclusions of Inger (1966), who found a high variability in the group, based on morphological characters.

ACKNOWLEDGEMENTS

We are grateful to R. Inger, who kindly confirmed the identification of the species based on photographs. I. De la Riva, M. Garcia-Paris and M. Tejedo contributed to the bibliographical research. B. Sanchíz provided useful comments to an earlier version of the manuscript. M. J. Littlejohn and H. Schneider critically read the manuscript and provided suggestions that improved it substantially. Sound analyses were performed in the facilities of the Estación Bio-Geológica del Ventorrillo (C.S.I.C.). This study was partially funded by projects CYCIT PB92-0091 and CYCIT PB91-0115-CO2.

REFERENCES

- Alcala, A. C. & Brown, W. C. (1956). Early life history of two Philippine frogs with notes on deposition of eggs. *Herpetologica* **21**, 241-246.
- Alcala, A. C., Joermann, G. & Brzoska, J. (1986). Mating calls of certain Philippine anurans (Microhylidae, Ranidae). *Silliman Journal* **33**, 31-47.
- Brzoska, J., Joermann, G. & Alcala, A. C. (1986). Structure and variability of the calls of *Polypedates leucomystax* (Amphibia: Rhacophoridae) from Negros, Philippines. *Silliman Journal* **33**, 87-103.
- Dubois, A. (1976). Chants et écologie chez les amphibiens du Népal. *Colloq. Int. Centr. Nat. Rec. Sci.* **268**, 109-118.
- Duellman, W. E., & Pyles R. A. (1983). Acoustic resource partitioning in anuran communities. *Copeia* **1983**, 639-649.
- Frost, D. R. (1985). *Amphibian species of the world*. Joint Venture of Allen Press, Inc. and The Association of Systematics Collections. Lawrence, Kansas, U.S.A.
- Gerhardt, H. C. (1988). Acoustic properties used in call recognition by frogs and toads. In *The Evolution of the Amphibian Auditory System*, 455-484. Fritsch B., Ryan M. J; Wilczynski W; Hetherington T. E; and Walkowiak W. (Eds). John Wiley & Sons, New York.

- Gerhardt, H. C. (1991). Female mate choice in treefrogs: static and dynamic acoustic criteria. *Anim. Behav.* **42**, 615-63
- Groombridge, B. (1992). *Global Biodiversity. Status of the Earth's living resources*. Chapman & Hall. London
- Heyer, W. R. (1971). Mating calls of some frogs from Thailand. *Fieldiana Zool.* **58**, 61-82.
- Heyer, W. R., Rand, A. S., Gonsalves, C. A., Peixoto, O. L. & Nelson, C. E. (1992). Frogs of Boraceia. *Arg. Zool. S. Paulo.* **31**, 231-410
- Inger, R. F. (1954). Systematics and zoogeography of Philippine amphibia. *Fieldiana Zool.* **33**, 181-253.
- Inger, R. F. (1966). Systematics and zoogeography of the amphibia of Borneo. *Fieldiana Zool.* **52**, 1-402.
- Inger, R. F. (1989). Four new species of frogs from Borneo. *Malayan Nature Journal.* **42**, 229-243.
- Inger, R. F. & Stuebing, R. B. (1989). *Frogs of Sabah*. Sabah Parks Publication N. 10. Sabah Parks Trustees. Kota Kinabalu. Malaysia.
- Inger, R. F. & Stuebing, R. B. (1991). A new species of frog of the genus *Leptobrachella* Smith (Anura: Pelobatidae), with a key to the species from Borneo. *Raffles Bulletin of Zoology* **39**, 99-103
- Kuramoto, M. (1986). Call structure of the rhacophorid frogs from Taiwan. *Sci. Rep. Lab. Amphibian Biol.* Hiroshima Univ. **8**, 45-68.
- Kuramoto, M. & Yong H.-S. (1992). Karyotypes of several frog species from peninsular Malaysia. *Herpetologica* **48**, 434-438.
- Littlejohn, M. J. (1981). Reproductive isolation: A critical review. In *Evolution and Speciation*, 298-334. Atchley W. R. and Woodruff D. S. (Eds). Cambridge University Press, Cambridge, U.K.
- Littlejohn, M. J. (1988). Frog calls and speciation: the retrograde evolution of homogamic acoustic signaling systems in hybrid zones. In *The Evolution of the Amphibian Auditory System*, 613-636. Fritzsche, B., Ryan, M. J., Wilczynski, W., Hetherington T. E. & Walkowiak W. (Eds). New York: John Wiley & Sons.
- Márquez, R., de la Riva, I. & Bosch, J. (1993). Advertisement calls of Bolivian species of *Hyla*. *Biotropica* **25**, 426-443.
- Matsui, M. (1979). Amphibians from Sabah I. Systematic and Natural History notes. *Contr. Biol. Lab. Kyoto Univ.* **25**, 303-346
- Matsui, M. (1982). Amphibians from Sabah II. Acoustic characteristics of three common anuran species. *Contr. biol. Lab. Kyoto Univ* **26**, 123-129.
- Matsui, M., Seto, T. & Utsunomiya, T. (1986). Acoustic and karyotypic evidence for specific separation of *Polypedates megacephalus* from *P. leucomystax*. *J. Herpetology* **20**, 483-489.
- Schneider, H. & Sinsch, V. (1992). Mating call variation in lake frogs referred to as *Rana ridibunda* Pallas, 1771. *J. zool. Syst. Evolut.-forsch.* **30**, 297-315.

Accepted: 6.1.95