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Acoustitic Characteristics of Three Species of the Genus *Amolops* (Amphibia, Anura, Ranidae)

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ABSTRACT—Advertisement call characteristics of *Amolops chunganensis* from western China, *A. larutensis* from Peninsular Malaysia, and *A. jerboa* from Borneo are described. The last species is sometimes grouped into a different genus, but all the three species are considered to constitute a single genus *Amolops* (sensu lato) from their unique larval morphology. Calls of the three species differ considerably from each other both in temporal and frequency patterns, and from these acoustic characteristics, the idea of subdividing this genus into discrete subgenera is supported, and the three species are classified as *A.* (*Amolops*) *chunganensis, A.* (*Amo*) larutensis, and *A.* (*Meristogenys*) *jerboa.* Calls of the three species differ in temporal patterns, but are similar in having rather high dominant frequencies and more or less clear frequency modulations. These common acoustic properties seem to be well adapted for the call to emerge above the heavy environmental noises.

INTRODUCTION

Asian ranid genus *Amolops* includes more than 32 species [10], and is characterized by peculiar larval ecology and morphology; they inhabit swift torrents and bear a large abdominal sucker [4]. Recently, Yang [10] and Dubois [2] divided this genus into distinct genera and subgenera, respectively. However, their classifications are based chiefly on adult and larval morphology, and other taxonomically important characteristics such as acoustic and biochemical ones are not included. Thus, it seems worth to reassess taxonomic treatments of these authors from approaches other than morphology.

The acoustic signal plays a very important role in the breeding behavior of anuran species, and is thus regarded as one of the key characteristics that are responsible for the speciation events in this animal group. Nevertheless, there are only a few anecdotal or incomplete reports on the acoustic characteristics of frogs of the genus *Amolops* [1, 5, 9]. On the other hand, in some anuran genera that were studied acoustically as well as morphologically, call structure has been known to parallel the morphological groups, and, therefore, has some phylogenetic significance [3, 6, 8]. In this paper we describe call characteristics of three species, i.e., *A. chunganensis* from China, *A. larutensis* from Peninsular Malaysia, and *A. jerboa* from Borneo, and assess validity of new taxonomic treatments on this genus.

MATERIALS AND METHODS

Recordings of calls were made in the field by the senior author using a cassette tape recorder (Sony TC-D5) with an external microphone (Sony ECM-23F). Temperature measurements were made at the time of recording using a quick recording thermistor thermometer (Takara A 600). The recorded calls were analyzed using computer programs, SoundEdit Vers. 2 or SoundEdit Pro (MacroMind-Paracomp, Inc.) by a Macintosh computer.

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RESULTS

Amolops chunganensis

Calls were recorded on Mt. Omei-shan at the altitude of 700 m, Sichuan, China, on 27 July 1992. Air temperature at the time of recording was 27.4°C. Males were observed to form a loose aggregation and call even in the daytime (1400 hr) either in the low bushes along streams (width<8 m) or on rocks in the streams with a moderate current.

The call (Fig. 1A) consisted of a continuous series of notes lasting more than 30 sec. Each note consisted of four to seven clear pulses (Table 1). The note length increased with the increment of number of pulses included (0.133 sec in four pulsed note to 0.259 sec in seven pulsed note). The length of inter-note interval, however, was not always proportional to the note length. The pulse repetition rate was nearly similar among notes with different number of pulses (30.0 per sec in four pulsed note and 27.0 per sec in seven pulsed note). Weak frequency modulations are present within a note, and the dominant frequency was initially about 3000–3400 Hz, but rose towards the end of the pulse series to about 3500–3800 Hz. Harmonics were absent.

Amolops larutensis

Calls were recorded at Frasers Hill, Larut Hill, and Gombak, Peninsular Malaysia, on 10–12 De-

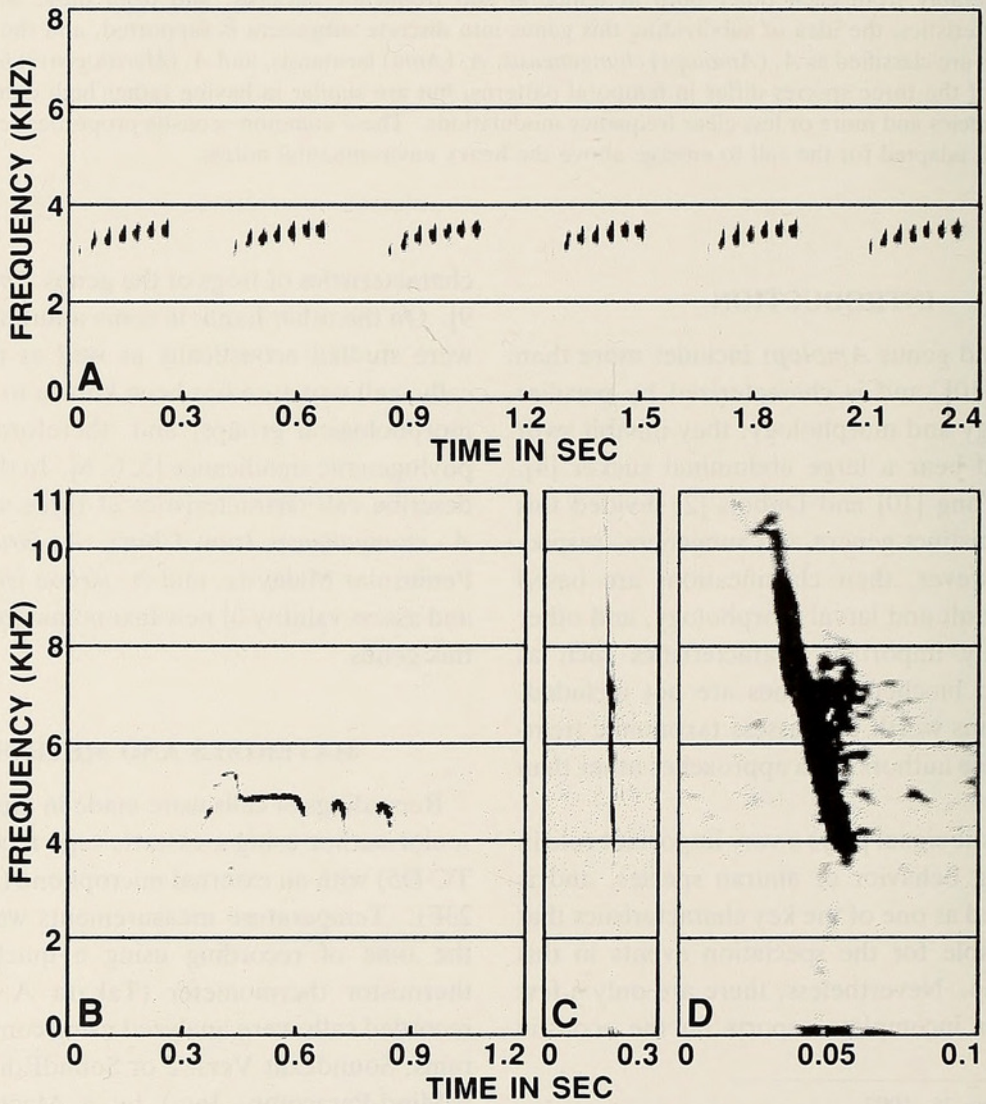

FIG. 1. Sonagrams of advertisement calls of *Amolops chunganensis* (A), *A. larutensis* (B), and *A. jerboa* (C, D).

TABLE 1. Call characteristics of three *Amolops* species (Mean ± 1SD, followed by sample size)

Species	Note length (sec)	Note interval (sec)	Initial frequency (Hz)	Final frequency (Hz)
Amolops chunganensis				
4 pulsed note	0.133 ± 0.002	0.217 ± 0.009	3440.0 ± 142.9	3798.0 ± 97.9
	10	9	10	10
5 pulsed note	0.170 ± 0.005	0.186 ± 0.021	3163.6 ± 192.4	3895.4 ± 169.4
	11	10	11	11
6 pulsed note	0.201 ± 0.004	0.219 ± 0.027	3250.0 ± 70.7	3487.5 ± 64.0
	10	8	7	8
7 pulsed note	0.259 ± 0.018	0.188 ± 0.023	3004.5 ± 230.7	3604.5 ± 96.0
	11	11	11	11
Amolops larutensis				
1st note	0.175 ± 0.006 *	0.077 ± 0.003	5440.0 ± 114.0	4625.0 ± 137.6
	6	6	5	6
2nd note	0.029 ± 0.002	0.090 ± 0.002	4804.1 ± 84.6	4387.5 ± 213.2
	6	6	6	5
3rd note	0.032 ± 0.001	—	4776.6 ± 39.4	4362.5 ± 175.4
	6	—	6	6
Amolops jerboa				
	0.042 ± 0.014	—	7152.9 ± 403.1	4266.6 ± 159.8
	17	—	17	6

* initial weak phase not included.

cember 1992, 2–3 January 1993, and 24 January 1993, respectively. Air temperatures at the time of recording varied from 19.3 to 21.7°C. Males called at night on rocks in or at the edge of streams (width < 5 m) with swift currents.

Calls were emitted with long intervals (22–37 sec). A call lasted about 0.49 sec and included three discrete notes (Fig. 1B). The first note was long and unpulsed, and included two continuous phases. The first phase was short (about 0.085 sec) and had marked frequency modulation; it rose gradually in frequency from 4300 Hz upto 5400 Hz and descended quickly to 4900 Hz. This phase, especially from the start to the point with the highest frequency, was weak and seldom traced in the sonagram, and therefore, its length is omitted in Table 1. The second phase was long (0.175 sec) and almost constant in frequency (about 4900 Hz), but with a slight frequency modulation in the final portion (to 4600 Hz). Each of the subsequent two notes were produced with an interval of 0.077–0.091 sec. They were short pulses (about 0.03 sec in length), but were similar to the second phase of the first note in frequency pattern. No harmonics are evident in either of the three notes.

Amolops jerboa

Calls were recorded on Mt. Gunung Serapi, at the altitude of 150 m, near Matang, Kuching, Sarawak, on 12 December 1990. Body temperature of males measured immediately after recording averaged 25.2°C. Males were calling at night on low trees along the edge of a swift stream (width < 5 m) with waterfalls.

The call (Fig. 1C, D) was emitted sporadically (intervals about 65–104 sec), and consisted of a very short, unpulsed note, lasting about 0.042 sec (Table 1). A call included two continuous phases, of which the first one was very short (about 0.004–0.014 sec) and had a marked frequency modulation; it descended quickly in frequency from over 11000 Hz down to about 10000 Hz and again rose to over 11000 Hz. This phase was only very weakly traced in the sonagram (Fig. 1D). The second phase was longer (0.020–0.074 sec), but with an even conspicuous frequency modulation, and the frequency decreased rapidly from about 11000 Hz to 3000 Hz. Dominant frequencies were traced at about 7100 and 4200 Hz ranges, and harmonic bands are often found between 4200–7800 Hz ranges.

DISCUSSION

In describing three new species of the genus *Amolops* from Borneo, the senior author [7] noted remarkable differentiation in eggs and larval morphology between Chinese and Bornean members of this genus and suggested that they represent different evolutionary lineages. Later, Yang [10] divided this genus into three distinct genera: *Amolops* Cope, 1865 from mainland Southeastern Asia, *Huia* Yang, 1991 from Java, Sumatra, Borneo, Thailand, and southern China, and *Meristogenys* Yang, 1991 endemic to Borneo. Dubois [2], on the other hand, retained only one genus *Amolops,* but divided it into four subgenera; he relegated Yang's [10] three genera (*Amolops, Huia,* and *Meristogenys*) to subgenera, and added a new subgenus *Amo* Dubois, 1992. According to their classifications, *A. chunganensis* and *A. jerboa* belongs to the genus or subgenus *Amolops* and *Meristogenys,* respectively, whereas *A. larutensis* is assigned to the genus *Amolops* by Yang [10] or subgenus *Amo* by Dubois [2]. Although Yang [10] adopted cladistic methods in his revision, his interpretation of a monophyletic group is ambiguous, and we think it more reasonable to recognize only one genus *Amolops* for frogs from Southeastern Asia that are united by a distinct synapomorphy (larval abdominal sucker). The problem is the number of lineages present within this genus.

As shown above, calls of the three species differ considerably both in temporal and frequency patterns, and from these acoustic characteristics, they seem to represent different lineages. Pope [9] noted that *Rana* (=*Amolops*) *chunganensis* from Fujian produced several kinds of calls, one of which seems to conform to the call described above. Kiew [5] noted that *Staurois* (=*Amolops*) *larutensis* had a shrill call hardly audible above the roar of the water. No exact data for calls are available for other members of the genus *Amolops* (sensu lato) except for Dubois [1], who briefly reported a call of a Nepalese frog which might be that of *A. afghanus* (*A. marmoratus,* according to Dubois [2]), the type species of the genus *Amolops.* No sonagram was given, but the call was reported to be a single note (length=0.2 sec) with a dominant frequency between 2000–2500 Hz. This frequency range is significantly lower than that of the three species described above, but this might be attributable to a difference in the body size. In the note length, the call seems to resemble the first note of *A. larutensis,* but it is impossible to make further comparisons because of the lack of additional data. No call data are available at present for members of *Huia* [10], either.

From our acoustic analyses, Dubois' treatment [2] seems better than Yang's one [10] in that *A. chunganensis* and *A. larutensis* are quite dissimilar in call characteristics, and are therefore to be split taxonomically. Thus, the three species are classified as *A.* (*Amolops*) *chunganensis, A.* (*Amo*) *larutensis,* and *A.* (*Meristogenys*) *jerboa.* It should be noted, however, Dubois' taxonomy [2] is far from complete, including important mistakes such as inclusion of *Rana taiwaniana* in his subgenus *Amolops* [2: p. 321]. The species actually is not a member of the genus *Amolops,* but is synonymous with *Rana swinhoana* (Matsui, Unpublished data). Future studies on additional species will demonstrate the relationships of acoustic characteristics and phylogeny of this genus.

Although fairly differentiated in characteristics, calls of the three species described herein were all emitted at the edge of rapid currents, where heavy noises, with additional songs of other frog species and insects, seem to prevent frogs from transmitting acoustic signals. The three species in common have calls with rather high dominant frequencies and more or less clear frequency modulations. On the other hand, they are different in the degree of these traits, and they even more differ in temporal patterns of calls. *Amolops chunganensis* gives nearly continuous calls with distinct pulses, but the frequency and degree of frequency modulation were lower than those of *A. larutensis* and *A. jerboa.* The call of *A. larutensis* is shorter and emitted only sporadically, but dominant frequency is higher and frequency modulation is more marked than in *A. chunganensis.* Finally, calls of

A. jerboa are shortest and emitted with longest intervals, but dominant frequency and degree of frequency modulation are most conspicuous among the three species. All of these different call characteristics seem to be well adapted for the call to emerge above the heavy environmental noises.

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REFERENCES

1 Dubois A (1976) Chants et ecologie chez les amphibiens du Nepal. Coll Int CNRS 268: 109–118

2 Dubois A (1992) Notes sur la classification des Ranidae (Amphibiens Anoures). Bull Mens Soc Linn Lyon 61: 350–352

3 Duellman WE (1970) The hylid frogs of Middle America. Monog Mus Nat Hist Univ Kansas 1: 1–753

4 Inger RF (1966) The systematics and zoogeography of the Amphibia of Borneo. Fieldiana: Zool 52: 1–402

5 Kiew BH (1990) Amphibian fauna of Taman Negara. J Wildlife and Parks 10: 96–108

6 Martin WF (1972) Evolution of vocalization in the toad genus *Bufo* In "Evolution in the Genus *Bufo*" Ed by WF Blair, Univ of Texas Press, Austin, pp 279–309

7 Matsui M (1986) Three new species of *Amolops* from Borneo. Copeia 1986: 623–630

8 Nelson CE (1973) Mating calls of the Microhylinae: descriptions and phylogenetic and ecological considerations. Herpetologica 29: 6–17

9 Pope CH (1931) Notes on amphibians from Fukien, Hainan, and other parts of China. Bull Amer Mus Nat Hist 61: 397–611

10 Yang DT (1991) Phylogenetic systematics of the *Amolops* group of ranid frogs of Southeastern Asia and the Greater Sunda Islands. Fieldiana: Zool (New Ser) 63: 1–42