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MATING CALLS OF CERTAIN PHILIPPINE ANURANS (MICROHYLIDAE, RANIDAE)

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The mating calls of five Philippine anurans are analyzed. Kaloula picta and K. conjuncta, both belonging to the family Microhylidae, have stereotyped and simple-structured mating calls. The calls of these two species differ in temporal parameters. In contrast, three species of the family Ranidae--Rana erythraea, R. signata and Ooeidozyga laevis--have more complex calls. Those of R. erythraea and Ooeidozyga laevis are very variable, each with different call types, and that of R. signata contains only one type. The calls of R. erythraea include frequency-modulated tone pips and harmonic elements, while those of the other two ranids have mainly pulsed signals. Mating calls of these Philippine frogs may be used in clarifying taxonomic problems.

The taxonomy of Philippine amphibians has been based mainly on morphological characters and only to a very limited extent on other biological features such as life history and ecology (Brown and Alcala, 1983; Heyer, 1971; Schneider, 1977; Taylor 1920, 1928). In recent years herpetologists have recognized the significant role of reproductive behavior in speciation processes (Blair, 1962; Salthe and Mecham, 1974). Mating calls, which constitute an important component in the analysis of reproductive behavior, have been shown to be useful in clarifying taxonomic questions and are now considered an essential part of species characterizations in anurans (Littlejohn and Oldham, 1968; Schneider, 1974, 1977).

In the present paper we describe the vocalizations of five common anuran species in the Philippines, two species in the family Microhylidae (Kaloula picta Duméril and Bibron and K. conjuncta Peters) and three species in the family Ranidae (Rana signata Guenther, R. erythraea Schlegel and Ooeidozyga laevis Guenther). Both species of Kaloula are restricted to the Philippines, but the three ranids also occur in Borneo, the Sunda Islands and other parts of Southeast Asia. It is hoped that our data on vocalization may provide an additional basis for the taxonomy of ranid and microhylid frogs in the Philippines.

MATERIALS AND METHODS

The calls were recorded under natural conditions in t field with a condenser microphone (Sennheiser K3/ME 80) a portable tape recorders (Uher Report 4200 and Sony TCM-5000 The analysis equipment consisted of a sonagraph (Kay 7029 A an oscilloscope with camera (Tonnies Recordine) and a spectr analyser (Nicolet UA 500 A). The sonagrams shown in this pap comprise a dynamic range of 20-25 dB; they are wide-band filter if nothing else is indicated. Mean values of call parameters a given with their standard deviations following the ± sign.

Most, but not all, of the calling frogs were captured aft recording. Identification of the uncaught individuals was bas on one of the authors´ (A.C.A.) familiarity with the calls of t species. Voucher specimens are deposited in the herpetologic collections at Silliman University and the Museum Alexand Koenig, Bonn, West Germany.

Air temperatures were recorded with a quick-readi Schultheis thermometer. Water temperatures were also recorded f species calling in the water.

RESULTS

Kaloula conjuncta.

The calls of this species were recorded at Bantaya Dumaguete City, Negros Island, in the rain on 19 and 24 Ju 1984, 2000 - 2100 h. Air and water temperatures were 26 a 25.5° C, respectively. The calling sites were edges of rai filled ditches. When calling, the males had their forelimbs land and hindlimbs in water. The population on Negros belon to the subspecies negrosensis Taylor (Inger, 1954).

A mating call series consists of 100 - 500 calls lasti 12 - 60 s. These calls are very short, with a mean duration only 8.8 ± 0.5 ms (n=15), and consist of a single note (Fig. 1 The period time of the calls is 85 - 170 ms ($\bar{x}$ = 120.2 ± 18. n = 240). Successive periods generally do not change by more tha 25 ms. However, in the whole series the rhythm may accelera and slow down several times, resulting in a large range periods (see example in Fig. 2). The frequency spectrum has maximum at 1030 ± 15 Hz (n = 15), with the second harmoni clearly present. In one of two animals, a third harmonic, abou 20 dB weaker than the fundamental, is identifiable. Additiona frequency portions with low intensity are found between 1 and Khz.

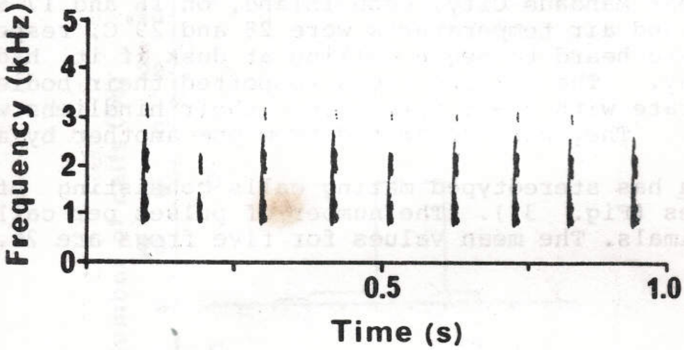

Fig. 1. Kaloula conjuncta. Sonagram of a section of a call series.

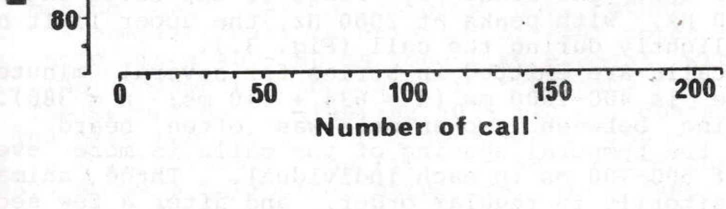

Fig. 2. Kaloula conjuncta. Period time of successive calls in a series of 207 calls.

Kaloula picta.

Recordings of this species were made in small ponds in rice field near Mandaue City, Cebu Island, on 16 and 17 Septembe 1983. Water and air temperatures were 28 and 29° C, respectively The frogs were heard to begin calling at dusk if it had raine during the day. The calling frogs supported their bodies on th muddy substrate with their forelimbs; their hindlimbs were fre in the water. They were separated from one another by at leas 30 cm.

K. picta has stereotyped mating calls consisting of 24 - 3 uniform pulses (Fig. 3.). The number of pulses per call differ among the animals. The mean values for five frogs are 26.4 - 33.

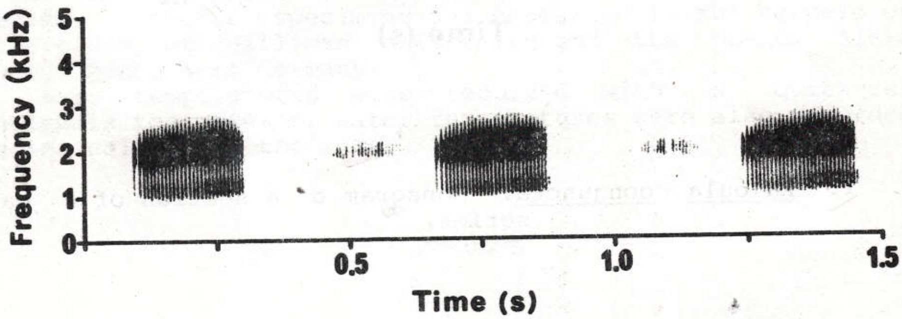

Fig. 3. Kaloula picta. Sonagram of three calls; in alternatio are two weak calls of a second male.

pulses per call (Fig. 4.). The call duration is also variable the mean durations for the same five frogs are 188 - 230 ms, wit a standard deviation of 6.6 ms. The factors responsible for th variations in these two parameters are not yet known.

The period time of the pulses is 7-9 ms in the middle par of the call, often longer at the beginning, and generally shorte toward the end. The frequency range of the calls extends fro 900 to 3000 Hz, with peaks at 2080 Hz; the upper limit and peak increase slightly during the call (Fig. 3.).

The calls are emitted in series for several minutes. Th period time is 400-1500 ms ($\bar{x}$ = 634 $\pm$ 140 ms; n = 380). Alter nate calling between two animals was often heard. In suc instances the temporal spacing of the calls is more even, wit periods of 500-700 ms in each individual. Three animals cal only transitorily in regular order, and after a few seconds on of them leaves the chorus. Active coordination of more than tw animals is doubtful.

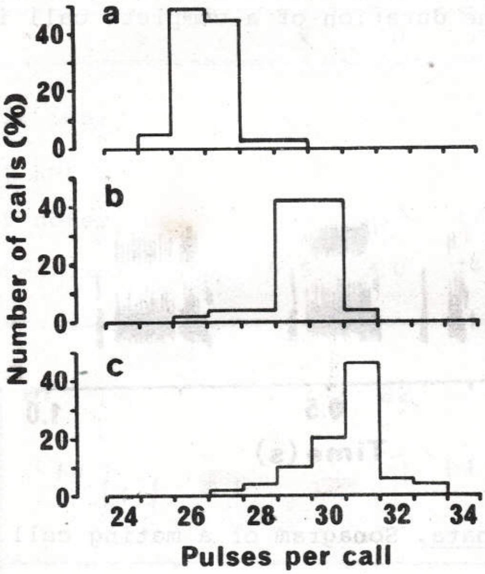

Fig. 4. Kaloula picta. Frequency distribution of the number of pulses per call in three individuals (a - c).

[illegible] signata.

Recordings of this species were made at Malinao, about 27 km west of Puerto Princesa, Palawan Island, on 23 June 1984, at 1900 h, with air temperature of 26.5°C. The frogs were calling from land, at the edge of a pond fed by a mountain stream. According to Inger (1954) the population on Palawan belongs to the subspecies moellendorffi Boettger.

The mating call has a complex but rather invariable structure. A complete call is composed of four notes (Fig. 5.). The first note is a 40 - 80 ms tone-like element with 3 - 4 harmonics. The fundamental increases in frequency from 750 Hz to [illegible] Hz. The second note, lasting 50 - 170 ms, contains 2 - 14 pulses. The last two notes have a duration of 150 - 250 ms and consist of 13 - 22 pulses. The first pulse in the three latter notes always shows a harmonical structure, with fast frequency modulations in a frequency range similar to that of the first note. The following pulses are clicklike, having a broad frequency spectrum extending from 900 to 3600 Hz, peaks being at [illegible] Hz, and are weaker by 10 dB at 2800 Hz. The pulses in the last three notes are ordered, with a period of about 9 - 10 m and only the last pulse is more separated in time. In 13 cal of one animal, the first note was missing three times and t last note once. The duration of a complete call is 760 - 1140 ($\bar{x}$ = 964 ± 140).

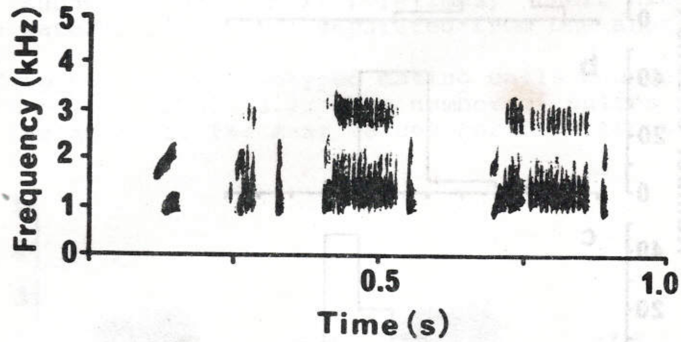

Fig. 5. Rana signata. Sonagram of a mating call.

Rana erythraea.

The calls of this species were recorded at Bantaya Dumaguete City, Negros Island, on 21 September 1983. The anima called from a medium sized pond in a coconut grove. Water and a temperatures were 30°C at 2000 h and 29°C at 2300 h.

Three types of calls can be recognized. The first type (A which has a mean duration of 580 ms, typically consists of 4 - notes (Fig. 6a). The period time of a note is 92 ms on t average; the intervals are often alternately longer and shorte resulting in a distinct rhythm. The last note may have a long interval. The temporal parameters are given in Table 1. T notes are all frequency modulated pure tones; only rarely is weak, second harmonic found above the fundamental. The type modulation is variable, mostly upward but sometimes downward both upward and downward. The single pulses cover a frequen width (difference between upper and lower limit) of 660 - 34 Hz. Within a call the frequency range or the dominant frequen decreases steadily, and only the last note may again rise pitch. The overall frequency range of a call ranges from abo 950 to 5300 Hz. The amplitude course of the notes characterized by a very steep onset; after 2 or 3 waves fu intensity has already been reached (Fig. 7a). Type A calls we mostly uttered when the animals made fast movements in flig after being startled or even without obvious disturbance.

Table 1. Characteristics of call type A in Rana erythraea.

	x̄	SD	N	MIN.	MAX.
Duration of call (ms)	582	212	50	248	1046
Number of notes per call	6.5	2.4	50	3	14
Period times of notes (ms)	92	33	120	52	184
Duration of notes (ms)	9.5	2.0	148	5.1	15.5

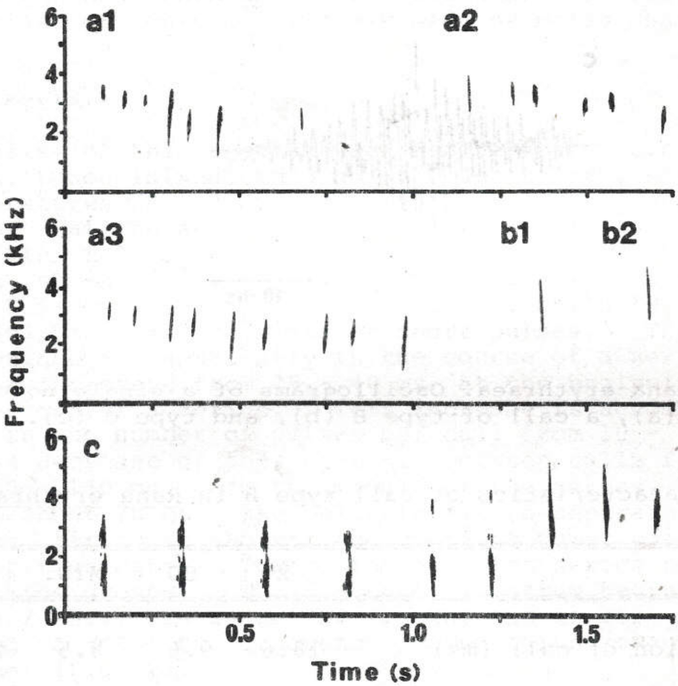

Fig. 6. Rana erythraea. Sonagram of 3 type A calls (a1 - a3), type B calls (b1 - b2), and a series of type C calls (c); this series is terminated by 2 notes similar to type A and one note similar to type B.

Type B calls consist of a single note of 18.6 ms duration c the average. The note is generally a downward sweeping ton (Fig. 6b). Only very long calls start with a faint upstroke c the frequency. At the end of the call the second harmonic ma appear with low energy. The frequency parameters are listed i Table 2. In contrast to the notes of type A, the amplitude c type B calls rises very slowly, and the maximum is not reache before two-thirds of the call duration (Fig. 7b). Calls of typ B are emitted singly and sparingly.

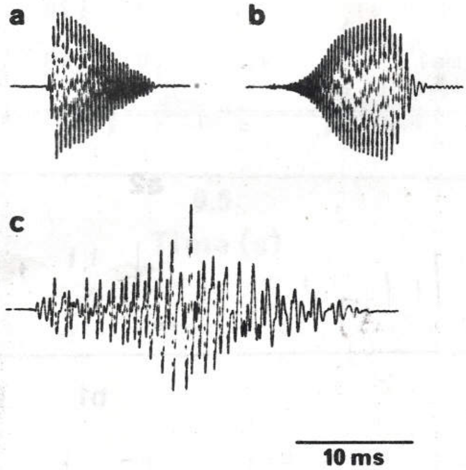

Fig. 7. Rana erythraea. Oscillograms of a single note of A-cal (a), a call of type B (b), and type C (c).

Table 2. Characteristics of call type B in Rana erythraea; n=45.

	$\bar{x}$	SD	MIN.	MAX.
duration of call (ms)	18.6	9.6	8.5	45.5
upper frequency limit (Hz)	4240	590	3480	5650
lower frequency limit (Hz)	1550	450	800	2640
width of sweep (Hz)	2690	660	1460	4580

The most frequent call is type C (Fig. 6c, 7c). Containing a single note , this call has a duration of 16 - 33 ms ($\bar{x}$ = 24.7 ± [illegible]; n = 120). The sonagram shows a fast up-and-down modulation of 2 - 4 harmonics (Fig. 6c). Overlap of the frequency ranges of the harmonics and additional non-harmonic portions results in a broad frequency spectrum beginning at 640 Hz and extending up to [illegible]00 - 4500 Hz. However, the energy decreases in the upper third of this range, so that type C calls clearly sound lower than type [illegible] calls. Type C calls occur more often in series, although they may occur singly. Typically, the frogs emit a series consisting of 10 - 20 calls of type C, with intervals decreasing from 600 - [illegible] ms at the beginning to 200 - 400 ms at the end. Following the type C calls are one to five notes closely resembling those of type A or type B; the distinction between the two is the different amplitude course described above (Fig. 6c). After an interval of 0.6 - 1.3 s a new series may start with C-calls. If several series succeed in this manner, they usually are shortened from one to the next through the reduction of the number of C-calls. Series of only C-calls are made by males chasing away intruders.

Occidozyga laevis.

The calls of this species were recorded in Quezon City, Metro Manila, Luzon Island, on 3 and 4 October 1983, with air and water temperatures 28 - 29°C. The animals were in water-filled road ditches. Calling activity usually started at dusk.

The calls of this frog are very variable. Typical are the call series shown in Fig. 8. These calls last 2.6 - 6.0 s ($\bar{x}$ = 4.3 ± 1.1; n = 40) and contain 10 - 27 calls ($\bar{x}$ = 18.4 ± [illegible]; n = 40). A call consists of short pulses. The temporal parameters change systematically in the course of a series. The call duration increases from 25 - 40 ms at the beginning to 80 - [illegible] ms at the end of a series. This increase is accompanied by an increase in the number of pulses per call from 10 - 14 to 18 - [illegible] and by a decrease of the intervals between calls from 300 - [illegible] ms to 100 - 130 ms. In the middle of the series, at a call duration of about 70 ms, the pulses begin to separate into two groups. The first is shorter and contains fewer pulses at a higher repetition rate. Toward the end of a series pulses may split into three groups. The frequency spectrum begins at 2 kHz (maxima at 3.2 kHz), is weaker at 7.5 kHz and is very weak at 10 kHz. During a call the frequency composition changes in a complex manner (Fig. 8).

Aside from these long series of calls there are often produced shorter ones consisting only of 4 - 10 calls lasting 1.3 - [illegible] s. The calls are divided into pulse groups from the beginning, numbering 2 - 5 (Fig. 9a). Frequently, single calls consisting of 1 - 6 pulse groups with a duration of 20 - 180 ms, depending upon the number of pulse groups, can be heard. These calls often start with a kind of "growling" formed by a long

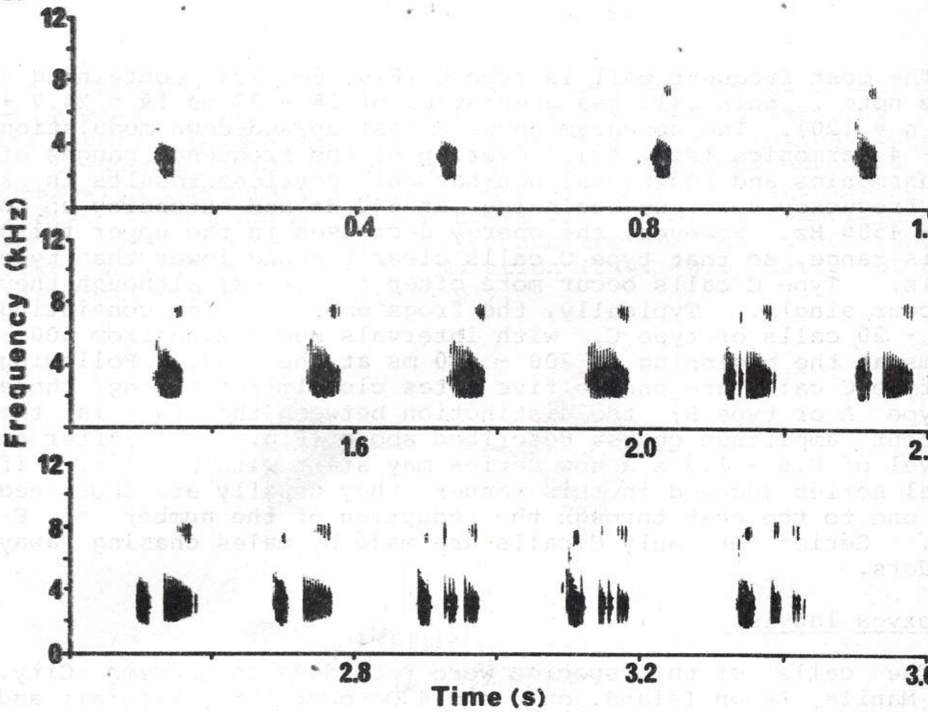

Fig. 8. Ooeidozyga laevis. Sonagram of a long call series.

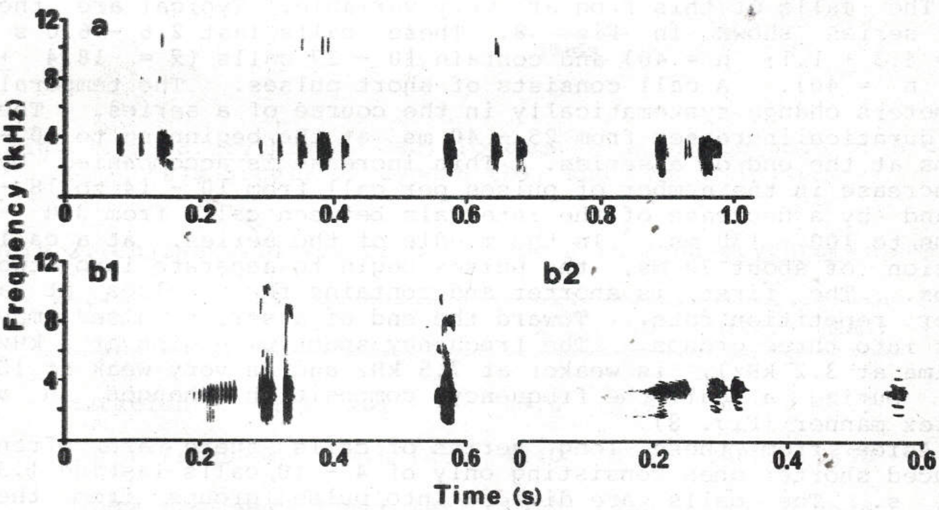

Fig. 9. Ooeidozyga laevis. Sonagram of a short call series (a) and a single call starting with a "growling" and followed by harmonic note (b); the same call was analysed with wide (b1) and narrow (b2) filters.

pulse train which begins very faintly and gradually increases in intensity (Fig. 9b). Sometimes 200 - 250 ms after a single call there is emitted a 30 - 40 ms harmonically-structured note. This latter has a fundamental of 2.9 kHz and two weaker harmonic bands above or consists of 8 - 12 harmonics in intervals of 550 Hz starting at 1650 Hz or is composed of both types (Fig. 9c). Single calls are often followed by the typically long mating call series in an interval of 2 s. This is not true, however, at the beginning of the daily calling period or for the males calling close to other calling males.

DISCUSSION

Both species of *Kaloula* have very simple structured calls. However these calls are clearly differentiated from each other, especially in terms of temporal parameters. Unequivocal labeling is supported by the high uniformity of the calls. The distinct difference in vocalization is noteworthy, as these two species look alike morphologically.

In contrast, the three ranids have more complex calls, containing differently designed notes. Whereas the calls of *Rana signata* are rather uniform, those of the other two species show a high variability, as is often the case in the genus *Rana* (Kuhn and Schneider, 1984; Mecham, 1971; Wahl, 1969).

In *Rana erythraea* the calls consist mainly of modulated tone pips or multiharmonic components. Such a frequency pattern is only rarely found in *Rana*; examples are *R. arvalis* (Schneider, 1973) and three Japanese species (Matsui and Utsunomiya, 1983). What more often occur are pulse-like vocalizations (Kuramoto, 1977; Matsui and Utsunomiya, 1983; Schneider, 1973). Matsui (1982) analyzed calls of *Rana erythraea* from Sabah (northern Borneo). His animals emitted a series of 6 - 11 notes resembling our type C calls in duration. But these are structured of fine pulses and extend to higher frequencies. Temperature, which generally influences call parameters (Schneider, 1973, 1977), was about 3 - 4 degrees lower in Matsui's recordings; this factor cannot account for the large differences in the calls of the Sabah and Negros populations of this species.

It is not known when the two populations were separated in the past. The species is presently found in large numbers on certain islands in the central Philippines but is absent on Mindanao and Palawan, the two large islands closest to Borneo. Since it is abundant wherever it occurs, local extinctions on Mindanao and Palawan seem unlikely. It is therefore conceivable that the species was accidentally carried by humans from Borneo (Inger, 1954).

Despite their variability, the calls of *R. erythraea* can be clearly classified into three specific types. We interpret the functional significance of these calls with the aid of notes taken at the time of recording. The typical mating ca[ll] obviously consists of a series of type C calls followed by so[me] notes of type A and B. Series with only C-calls are also utter[ed] in aggressive interactions, so these calls may be directed [to] other males. The higher pitched notes at the end of the norm[al] mating call series probably represent the main female-attracti[ng] signal. In several anuran species such a partitioned function [of] optional or obligatory compound calls can be demonstrat[ed] (Arak, 1983; Narins and Capranica, 1978; Wells, 1977). Fa[st] movements of the animals were always correlated with type [A] calls. A distinct call in a similar situation was described [in] Rana temporaria by Van Gelder et al. (1978), who interpret t[hese] calls as an announcement of the sex of the callers to near[by] males. It remains to be determined whether the A-calls serve t[he] same function in Rana erythraea.

The classification of the calls of Ooeidozyga laevis is mo[re] difficult. The long call series is unequivocally the typica[l] vocalization at the height of the calling activity. Other calls called short series or single calls, have few structura[l] peculiarities, so that a clear function cannot yet be ascribed t[o] them. Possibly, they are reflections of a lower motivationa[l] status of the frogs. Heyer (1971) described three call types o[f] O. laevis from Thailand. One of them resembles our harmoni[c] notes. Beyond this resemblance, the calls differ very much fro[m] those of Philippine frogs from Luzon Island. One differen[ce] noted is the lack of subdivision of the 30 - 170 ms calls [or] notes into pulses in Heyer's recordings. More samples from oth[er] localities are needed to relate calls of the two population[s,] possibly through intermediate types, and to distingui[sh] conservative structural features from those that are more easil[y] changed by evolution. A comparative study could also yield hin[ts] about the history of dispersal in this species.

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LITERATURE CITED

Arak, A. 1983. Vocal interactions, call matching an[d] territoriality in a Sri Lankan treefrog, Philautus leucorhinu[s] (Rhacophoridae). Anim. Behav. 31:292-302.

ir, W. F. 1962. Non-morphological data in anuran classification. Syst. Zool.11:72-84.

wn, W. C. and A. C. Alcala 1983. Modes of reproduction of Philippine anurans. In: Advances in herpetology and evolutionary biology: Essays in honor of Ernest E. Williams. A. G. J. Rhodin and K. Miyata, eds. Museum of Comparative Zoology, Cambridge, Mass.

der, J. J. van, P. M. G. Evers and G. J. M. Maagnus 1978. Calling and associated behaviour of the common frog, Rana temporaria, during breeding activity. J. Anim. Ecol. 47:667-676.

er, W. R. 1971. Mating calls of some frogs from Thailand. Fieldiana: Zool. 58:61-82.

er, R. F. 1954. Systematics and zoogeography of Philippine Amphibia. Fieldiana: Zool. 33:181-523.

m, B. and H. Schneider 1984. Mating and territorial calls of Rana ridibunda and their temperature dependent variability. Zool. Anz. 212:273-305.

amoto, M. 1977. Mating call structures of the Japanese pond frogs, Rana nigromaculata and Rana brevipoda (Amphibia, Anura, Ranidae). J. Herpet. 11:249-254.

lejohn, M. J. and R. S. Oldham 1968. The Rana pipiens complex: mating call structure and taxonomy. Science 162:1003-1005.

sui, M. 1962. Amphibians from Sabah II. Acoustic characteristics of three common anuran species. Contr. Biol. Lab. Kyoto Univ. 26:123-129.

sui, M. and T. Utsunomiya 1983. Mating call characteristics of the frogs of the subgenus Babina with reference to their relationship with Rana adenopleura. J. Herpet. 17:32-37.

ham, J. S. 1971. Vocalizations of the leopard frog, Rana pipiens, and three related Mexican species. Copeia 1971:505-516.

ins, P. M. and R. R. Capranica 1978. Communicative significance of the two-note call of the treefrog Eleutherodactylus coqui. J. Comp. Physiol. 127:1-9.

the, S. N. and J. S. Mecham 1974. Reproductive and courtship patterns. In: Physiology of the amphibia II, B. Lofts, ed. Academic Press, New York.

neider, H. 1973. Die Paarungsrufe einheimischer Ranidae (Anura, Amphibia). Bonner Zool. Beitr. 24:51-61.

__________ 1974. Structure of the mating calls and relationships of the European tree frogs (Hylidae, Anura). Oecologia (Berl.) 14:99-110.

__________ 1977. Acoustic behavior and physiology of vocalization in the European tree frog, Hyla arborea (L.). In: The reproductive biology of amphibians, D. H. Taylor and S. I. Guttman, eds. Plenum Press, New York.

lor, E. H. 1920. Philippine amphibia. Philip. J. Sci. 16:213-359.

____________ 1928. Amphibians, lizards and snakes of Philippines. In: Distribution of life in the Philippines, Dickerson, ed. Bureau of Science, Manila.
Wahl, M. 1969. Untersuchungen zur Bio-Akustik des Wasserfrosc Rana esculenta (L.). Oecologia (Berl.) 3:14-55.
Wells, K. D. 1977. The courtship of frogs. In: The reproduct biology of amphibians, D. H. Taylor and S. I. Guttman, e Plenum Press, New York, London.

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