Korean J. Zool. 39:207-214, 1996

The Classification of Call Types in Genus *Hyla* in Habitats Around South Korea

Shi-Ryong Park*, Se-Min Cheon, and Suh Yung Yang+

Department of Biology Education, Korea National University of Education, Chungbuk 363-791; +Department of Biology, Inha University, Inchon 402-751, Korea

Five call types of the genus *Hyla* in habitats around South Korea were classified according to some attributes of their advertisement calls (note duration, note interval, dominant frequency, sonagram pattern). Among the call types, the E-type was more distinctive than the other call types in that it had a metal sound and much longer note duration and note interval. This result indicated that some divergence had occurred in the advertisement call of the genus *Hyla*, though this was found in a limited number of regions and its occurrence was small.

KEY WORDS: Call Type, Genus *Hyla*, Note, Dominant Frequency, Advertisement Call

Savage (1973) suggested that Palearctic treefrogs of the genus *Hyla* were apparently derived from North American treefrogs, which invaded Eurasia through the Bering land bridge in the late cenozoic period. Thus, all of the 10 or so species currently recognized in the Palearctic region may have a single stock and have diverged rather recently (Gorham, 1974; Schneider, 1974; Duellman, 1977). Male treefrogs call at night, usually from spring to late summer and in the same place such as a pond in a rice field. Females, who are ready to lay eggs, identify and localize the male on the basis of his calls, and usually initiate sexual contact (amplexus) by moving close to or touching the male. Because the male indiscriminately tries to clasp any other frog of comparable size that moves near him, it is the female's task to make a correct identification, and she must often do so in choruses consisting of a dozen or more anuran species (Gerhardt, 1983).

The evolutionary significance of the mating calls of anuran males lies, at least partly, in attracting homospecific females. Consequently, the calls that they produce function as primary, species-specific, premating isolating mechanisms in anuran speciation (Blair, 1958). Of course, temperature affects at least some of the temporal properties of the mating calls of all frogs and toads studied to date (Schneider, 1974; Blair, 1958; Gerhardt, 1982). It also affects the preferences of female frogs. Gerhardt (1978) showed that female *Hyla* vesicolor preferentially responded to sigals similar in temporal properties to those produced by a conspecific male at about the same temperature.

Because of the evident species-specificity that is critical for premating isolation, mating calls of anurans are regarded as one of the most important diagnostic characteristics of the species. Call structures are most useful in distinguishing between similar species (Kuramote, 1980). Acoustic behavioural studies of several species have identified many of the physical properties of the vocal signals produced by the male that are important for sound pattern recognition by the female. Investigations of the calls of anuran species have demonstrated that their mating calls

*To whom correspondence should be addressed.

possess species-specific characteristics despite the fact that these characteristics vary with temperature and body size. Therefore, mating calls are as suitable for species identification as morphological features, and are sometimes even better (Wahl, 1969). Moreover, the analysis of mating calls provides evidence of the phylogenetic relationships of populations and species (Nevo and Schneider, 1983). For instance, four call types of *Rana pipiens* recognized by Littlejohn and Oldham (1968) proved to be four distinct species (Pace, 1974). This study aims to characterize ating calls of the genus *Hyla* of South Korea based on auditory sense, calling behaviour and the physical properties derived from sonagraph analysis. These results will be compared to the results on *Hyla japonica* and *Hyla suweonensis*, which have already been published by Kuramoto (1980) and Yang *et al.* (1981). These results will provide a good basic clues in classifying the genus *Hyla* in habitats around South Korea.

Materials and Methods

The mating calls of over 300 treefrogs inhabiting 17 regions around South Korea were recorded from March to July in 1994 and 1995 (Table 1). During each recording, we observed calling behaviour and measured the air temperature and water temperature. A Uher 4000 portable tape recorder, Sony Three-headed cassette recorder (TCM-5000EV) and condenser microphone (type AKG c1000s) were used throughout this study. The microphone was usually held 0.5 m from the calling male. The calls were analyzed by a Kay elemetric sonagraph 5500. The wide filter (0-8000 Hz) was used to obtain an accurate measurement of most of the temporal parameters. Transform size was fixed at 100 pts (300 Hz), but it changed to 1024 pts when we established a long-time axis to analyze the pulse structure. The properties analyzed in this manner included note duration, inter-note interval, the number of pulses per note, pulse repetition rate and dominant frequency. Pulse repetition rate was calculated from the equation (N-1/note duration time $\times$ 100; where N = the number of

Table 1. The recording date, water temperature range and the number of individuals recorded and analyzed in 17 regions.

	Recording date (yy/mm/dd)	Temperature range (°C)	Number of recorded individuals	Number of analyzed individuals
Ganghwa	94. 6. 17	18 - 20	19	15
Kurye	94. 6. 29	17 - 19	16	14
Yeongduk	94. 6. 14	16 - 18	12	18
Jindo	94. 6. 28	19 - 20	11	11
Byeonsan	94. 5. 28		3	2
Yangyang	94. 6. 15	14 - 19	25	15
Jeomchon	94. 6. 13	14 - 21	21	18
Daecheon	94. 6. 8	16 - 18	25	17
Anyang	94. 6. 5	21 - 23	7	7
Hwacheon	94. 6. 16	16 - 18	35	18
Jeju	94. 6.24 - 6.25	21 - 22	8	8
Geochang	94. 5.7 - 6.12	13 - 17	42	18
Gangnae	94. 4.	13 - 16	12	9
Naju	94. 5. 18	12 - 15	15	13
Suweon	94. 5.23 - 6.18	16 - 22	22	14
Jido	94. 6. 9	19 - 20	31	15
Pyeongtaek	95. 6. - 7.	19 - 24	12	10
	94. 4. - 95. 7.	12 - 23	316	222

pulses). Inter-note interval is defined as the time from the beginning of one note to the beginning of the next note. Because of the variability of the calling activity of the frogs in the field, the actual number of calls analyzed per individual differed from one another and data were obtained by randomly selecting, measuring and averaging. All these analyses were executed using an SPSSpc+ package.

Results

The characteristics of each call type in genus *Hyla*

The typical characteristics of genus *Hyla*'s mating calls, represented by sonagram, were as follows: the mating calls were emitted in series and composed of many notes (pulse group) which were also composed of fine pulses (Fig. 1). The morphological features of the note were mostly unchanged from call beginning to end. Only the temporal features showed variation owing to environmental factors; namely temperature, motivations, etc. But we also found other strange notes, something like a metal sound, which could be discerned clearly through our auditory system. They showed various patterns during calling, some discontinuous and others continuous. They could be identified by sonagram analysis. We classified five call types from 222 individuals (Fig. 2). The basis we used was mostly the note features: how they were shaped, how they were composed, how they were arranged by pulse and band, that is, the location of the band, and the proportion of the band length within the note. We also compared the entire call pattern and calling behaviour.

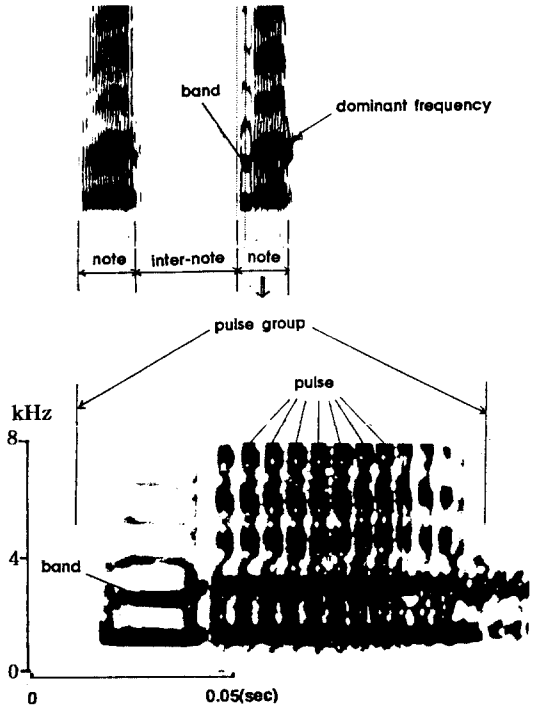

Fig. 1. The structure of *Hyla*'s call and related acoustical terms

A-type

This was the typical call pattern of genus Hyla and we collected this pattern most often from the 222 individuals. The note of this call pattern was composed of only 13-23 pulses and no bands appeared. The note length and the note interval notes showed slight differences from one another but had a tendency to become shorter as the temperature rose. The anterior parts of the pulse group showed lower resonance width and this seemed to be related to the physical phenomena accompanied by the initial movement of the call sac. Sometimes 1-3 pulses in the pulse group were separated by a little interval from the main group, and we could not discern these calls aurally. The average note duration time of this call type was 0.105 ± 0.019 (sec), the interval time between notes was 0.190 ± 0.062 (sec) and dominant frequency was 2927.99 ± 243.43 (Hz)

B-type

The note of this call was basically the same as the A-type call but sometimes note variation (notes with some bands) occurred intermittently. The location of the band in the pulse group showed differences according to individuals; most individuals had the note with an anterior band and it frequently came into sight at the start of the call after a long period of silence, but we found some individuals that had the note in the middle band or posterior band. During calling, these note variations appeared intermittently while

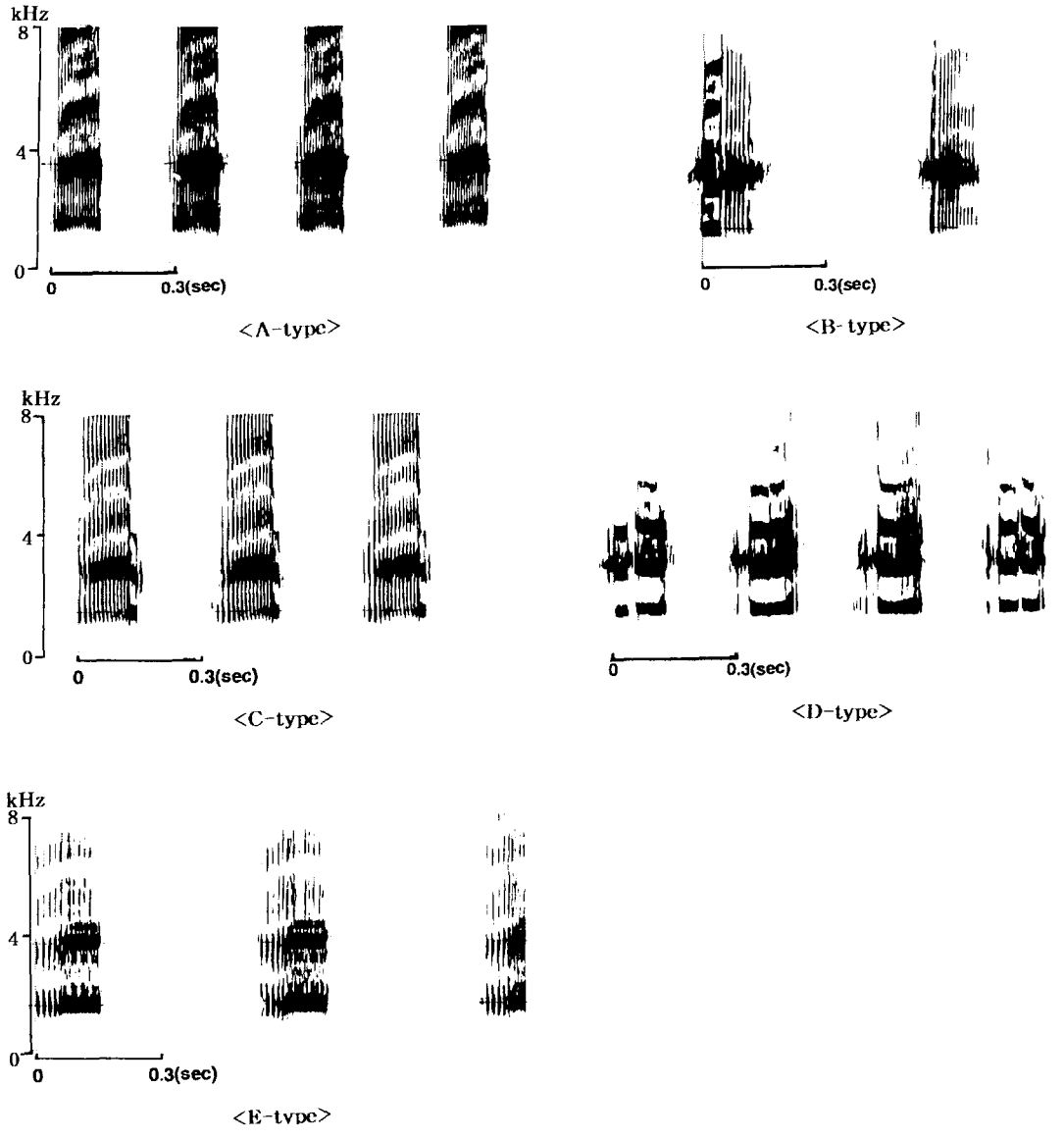

Fig. 2. The sonagram patterns of each call type

maintaining the original pattern, something like the A-type. The proportion of the band in the pulse group constituted about 1/10-3/10. The average note duration time was 0.095 ± 0.020 (sec), the note interval was 0.19 ± 0.064 (sec) and dominant frequency was 2892.308 ± 216.830 (Hz).

C-type

The note of this call type differed from that of other call types in both frequency and temporal characteristics. The note was longer and repeated at much longer intervals. The note was composed of two phases (pulse phase and band phase), similar to the B-type but different because it showed a continuous note pattern and the band phase in the pulse group appeared only in the

posterior part of the note. The dominant frequency of the pulse phase was not in accord with the band phase, and the pulse phase showed a slightly higher frequency. We could discern this call type aurally because it had a higher tone like a metal sound.

D-type

The note of this call type contained only the band phase with no pulse phase, and this note pattern was maintained continuously from the call beginning to the end. It had the highest tone, something like a metal sound.

E-type

The note of this call type consisted of two continuous phases (pulse phase and band phase) and did not change its pattern during calling. The band phase was located in the posterior part of the pulse group and the proportion of the band constituted over 2/3 of the note. The dominant frequency of the pulse phase was consistent with that of the band phase and this provided the important clue to be able to discern E-type from C-type. At the same temperature, the note duration and the interval between notes were longer than compared with C-type.

The distribution of each call type

Table 2 shows the distribution of genus Hyla according to each call type. The A-type call was distributed evenly around South Korea and was possessed by most of the genus Hyla (85.14%). The B-type call was thought to be distributed over the regions of the experiment but the numbers collected were so small (9.91%) that we had difficulty in defining a new call type. We think this call type may be a transitional call which emerges during changes to calling behaviour. C, D and E-type calls appeared in some limited regions and the number of individuals was very small (4.95%).

Temperature effects on specific call properties

Analysis of covariance (ANCOVA) was carried out on each attribute of the notes, with temperature and region as the covariants and call type as the grouping factor. There was a significant effect of temprature on note duration but not on note interval and dominant frequency ($P<0.05$). This result is so suggestive that we may be able to use not only the sonagram pattern but also note duration to classify call type. There was a significant negative correlation between temporal features and temperature (Table 3). The A-type call showed that the note duration was more negative correlated than note interval was,

Table 2. The distribution of each call type collected in 17 regions

	A-type	B-type	C-type	D-type	E-type	Sum
Durye	13	1				14
Ganghwa	12	3				15
Yeongduk	16	2				18
Jindo	10	1				11
Byeonsan	2					2
Yangyang	13	2				15
Jeomchon	16	2				18
Daecheon	16	1				17
Anyang	5	2		1		8
Hwacheon	15	3				18
Jeju	8					8
Geochang	17	1				18
Gangnae	9					9
Naju	11	2				13
Suweon	11	2		1		114
Jido	15					15
Pyeongtaek			3		6	9
Sum	189	22	3	2	6	222

Table 3. Correlation between temporal features and temperature according to call types

	Note duration	Inter-note interval	Number of pulses
A-type	-0.6472**	-0.4521**	-0.3086**
B-type	-0.5468**	-0.6326**	

**: singnificant P<0.0001

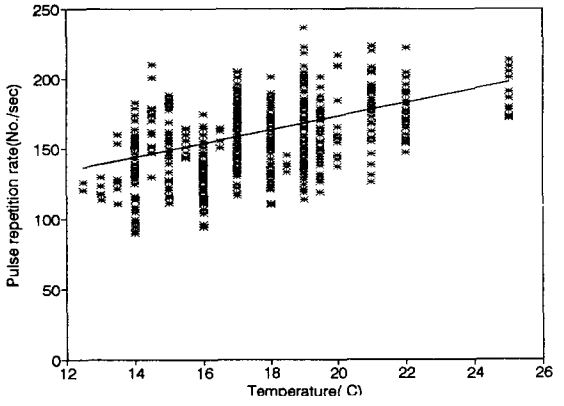

Fig. 3. The variation of PRR (pulse repetition rate) in A-call types according to temperature; Y = 75.21432 + 4.90527 × Temperature (P, 0.000)

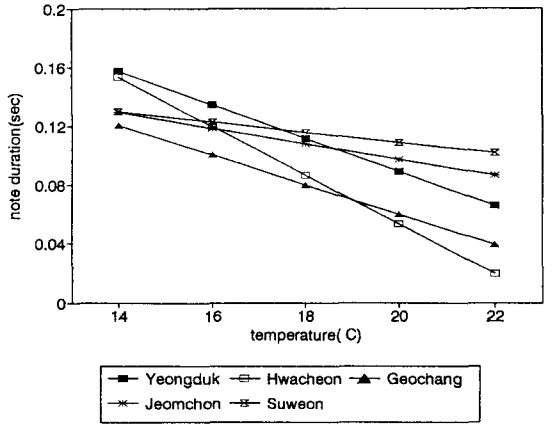

Fig. 4. Comparison of the regression line of note duration in five regions (Yeongduk, Hwacheon, Geochang, Jeomchon, Suweon)

but the B-type showed the opposite results. The pulse repetition rate showed an increased pattern as the temperature rose (Fig. 3). The slope of regression equation was different for each region and there were distinct divisions as temperature rose to extremes (Fig. 4).

Discussion

The homogamic system of anuran amphibians, in which acoustic communication plays a major part, has been the subject of intensive study and, thus, is suitable for investigation of the origins of positive assertive mating. Males emit a conspicuous and distinctive signal, the advertisement call, and reproductively ripe conspecific females are attracted to the signal. Where several syntopic species are simultaneously breeding, the advertisement call of each taxon is distinct, and positive phonotaxis by females is directed to these conspecific signals (Littlejohn *et al.*, 1993). Furthermore, the structure of the advertisement call in anurans is largely genetically determined (Gerhardt, 1983).

Sound spectrogram patterns of genus *Hyla* in habitats around South Korea resembled each other very much in that they showed similar patterns in pulse, note and dominant frequency. But detailed analysis could make it possible to find differences and in this study we classified genus *Hyla*'s call into five types based on sonagram patterns and temporal features. Each call type could also be recognized aurally because the notes with a band phase had a metallic sound. Each call type resembled each other in the temperature relations of note length and note interval. They also had negative correlation, but the degree of correlation differed. For example, the E-type call had much longer note duration and note interval than the other call types. These differences may be of biological significance in that they could provide the potential for directional selection during a subsequent interactive phase of speciation. We used water temperature to investigate the relation with temporal features. But there were some problems in measuring temperature. Previous researchers measured temperature differently from one another; some measured air temperature, some measured water temperature, some measured cloacal temperature,

some measured oesophageal temperature. Much of the data gathered previously could not be compared confidently because of these differences in temperature measurement. Gayou (1984) recommended that cloacal or oesophageal temperatures should be the standard method for recording the calling temperature because environmental fluctuations in air or water temperature can then be ignored. So we propose that the next researcher who consider what to measure had better select the Gayou's way.

According to previous research reported by Kuramoto (1980) and Yang *et al.* (1981), it is thought that the A-type call belongs to *Hyla japonica* and the E-type call belongs to *Hyla suweonensis*.'s because the sonagram patterns shown in those papers were in accord with our data. The other call type (B, C, D-call type) gave us a lot of trouble in making decision first, but they proved to be *Hyla japonica*'s call through the genetic research executed by Yang (1995), a co-researcher performing genetic analysis with isozyme. So, we can think that various call variation may happen in *Hyla japonical's* cal and this finding warrants further investigation through the obtaining of larger numbers of recording. During our research, we found *Hyla suweonensis* only in a restricted region in GyeongGi-Do, though we tried to collect genus *Hyla*'s call all around the regions as many as possible. *Hyla suweonensis*, which had been found in near the Suweon in 1980 by Kuramoto, was not likely to distribute all around the South Korea yet.

Kuramoto (1980) reported that *Hyla suweonensis* called throughout the day and night with a distinct activity peak at night while *Hyla japonica* called only at night. But we think that all o the genus *Hyla*, including *Hyla suweonensis,* call only at night for mating. Of course, we found some individuals calling in the day time, but these calls could not be considered mating calls because they came from forests or mountains and not from breeding places, and the individuals did not show continuous calling behaviour but the calls were very intermittent and short. Most of the individuals with A-type calls, which we thought to be the *Hyla japonicas* call, called on the banks of rice paddies, but some of them called in the middle of rice paddies. Therefore, we think more delicate observations are needed to decide the species correctly.

Acknowledgements

The present study was supported by the Basic Science Research Institute Program (BSRI-94-4423), Ministry of Education, Korea.

References

Blair, W.F., 1958. Call differences as an isolation mechanism in Florida species of hylid frogs, *Q. J. Fl. Acad. Sci.* **21:** 32-48.

Duellman, W.F., 1977. Liste der Rezenten Amphibien und Reptilien. Hylidae, Centrolenidae, Pseudidae. Das Tierreich, Lief. 95. Water de Gruyter, Berlin and New York.

Gayou, D.C., 1984. Effects of temperature on the Mating Call of *Hyla vesicolor. Copeia* **1984:** 733-738.

Gerhardt, H.C., 1978. Temperature coupling in the vocal communication system of the gray tree frog, *Hyla versicolor. Science* **199:** 992-994.

Gerhardt, H.C., 1982. Sound Pattern Recognition in some North American Treefrogs (Anura: Hylidae): Implication for Mate Choice. *Am. Zool.* **22:** 581-595.

Gerhardt, H.C., 1983. Acoustic communication in treefrogs. *Verh. Dtsch. Zool. Ges.* **1983:** 25-35.

Gorham, S.W. 1974. Checklist of World Amphibians Up to January 1, 1970. The New Brunswick Museum, Saint John.

Kuramoto, M., 1980. Mating Calls of Treefrogs (Genus *Hyla*) in the Far East, with Description of a New Species from Korea. *Copeia* **1980:** 100-108.

Littlejohn, M.J. and Oldham, R.S., 1968. *Rana pipiens* complex: mating all structure and taxonomy. *Science* **162:** 1003-1005.

Littlejohn, M.J., G.F., Watson, and J.R., Wright, 1993. Structure of Advertisement Call of *Litoria ewingi* (Anura: Hylidae) Introduced into New Zealand from Tasmania. *Copeia* **1993:** 60-67.

Nevo, E. and Schneider, H., 1983. Structure and variation of *Rana ridibunda* mating call in Israel (Amphibia: Anura). *Isr. J. Zool.* **32:** 45-60.

Pace, A.E., 1974. Systematic and Biological Studies of the Leopard Frogs (*Rana pipiens* complex) of the

United States, Misc. Publ. Mus. Zool. Univ., Michigan.
Savage, J.M., 1973. The Geographic Distribution of Frogs: Patterns and Predictions, In: Evolutionary Biology of the Anurans (Vial, J.L., ed.). Univ. Missouri Press, Columbia, pp. 351-445.
Schneider, H., 1974. Structure of mating calls and relationships of the European tree frogs (Hylidae, Anura). *Oecologia* **14:** 99-110.
Wahl, M., 1969. Untersuchungen zur Bio-Akustik des Wasserfrosches *rana esculenta*. *Oecologia (Berl.)* **3:** 14-55
Yang, S.Y., 1995. Intra- and Interspecific Diversity and Speciation of the Family Hylidae and Discoglossidae, Report of Basic Science Research Institute Program, Ministry of Education.
Yang, S.Y., Park, B.S. and Son, H.J., 1981. Species Comparison of the Genus *Hyla* in Korea. *Bull. I.B.S. Inha Univ.* **1981:** 1-9.

(Accepted February 22, 1996)

한국에 서식하는 청개구리(Genus *Hyla*)의 소리 유형에 대한 분류

박시룡 · 천세민 · 양서영+(한국교원대학교 생물교육과, +인하대학교 생물학과)

한국에 서식하는 *Hyla*속의 advertisement call을 소리의 물리적 형태(음절의 지속 시간, 음절의 간격, 주파수, 소리의 형태)에 따라 5가지의 소리 유형으로 분류하였다. 이들 소리 유형 가운데, E-형은 금속성 음을 띠며, 다른 유형의 소리에 비하여 훨씬 더 긴 음절의 지속 시간을 가지며 또한, 음절의 간격에 있어서 많은 차이가 나타났다. 비록 이 소리가 제한된 지역 과 출현의 빈도는 작았지만, 이 call은 청개구리 속의 advertisement call에서 발산이 나타났음을 보여주었다.