Korean J. Ecol., 23(4): 309~313, 2000

Call Types of Dybowski's Brown Frog and Their Variations from Two Recording Areas

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ABSTRACT: Since specific types and physical characteristics of anuran calls can represent reproductive qualities of a calling male, anuran calls have been studied in context of mate choice. We in here report call types of *Rana dybowskii* and their variations from two different recording sites. Calls of *R. dybowskii* are classified to three types based on their physical characteristics and behavioral observations: 'A-call' functions to advertise locations of a calling male and to attract potential mates. A territorial male emits 'B-call' only during male-male interaction. 'C-call' is released when a male frog was clasped by another male. The A-call from two recording sites, Miwon and Wonju, shows high variations in their call characteristics.

Key Words: *Rana dybowskii*, Call, Geographic variation

INTRODUCTION

Most anurans have a complex vocal communication system, which plays an important role in mate choice and social life (Wells 1977). To understand such a communication system, it is essential to categorize their call types. Most species have several call types. Such calls include advertisement call, encounter call and release call (Wells 1977).

Advertisement call, which is used in mate choice, shows high variation in their physical parameters such as dominant frequency and call duration (Nevo and Schneider 1983, Radwan and Schneider 1988). In most species snout-vent length (SVL) is negatively correlated with the dominant frequency of calls released (Schneider and Joermann 1988). Although there are several contradictary results, larger males have better territory and are more frequently selected by females (Stebins and Cohen 1995). Thus, anuran calls may be selected in context of sexual selection. For example, *Hyla versicolor* females use males' calls to select their potential mates who may have highest reproductive fitness (Gerhardt 1991).

Anuran calls vary region to region by habitat condition and physiological state in the same species (Stebins and Cohen 1995). At this point, vocal signal of anurans is used in phylogenetic classification. Analysis of the variation of anuran vocal signal makes the classification by morphology and isozyme analysis more reliable (Cocroft and Ryan 1995).

In the family Ranidae, call types from three species, *Rana rugosa*, *Rana plancyi chosenica* and *Rana nigromaculata*, were classified in Korea (No and Park 1992, Park and Yang 1997, Park *et al.* 1998).

The frog *Rana dybowskii* is an endemic species in Korea and breeds in early spring in small natural and artificial ponds (Kang and Yoon 1975). They lay eggs in early spring and spend summer at hills or grassland near the breeding sites. In this species, its call types and their variation have not been reported.

MATERIAL AND METHOD

Calls of *R. dybowskii* were recorded at Miwon, Chungbuk (36°42'N, 127°42'E) and Wonju, Kangwon (37°25'N, 128°03'E) in 1997 and 1998 breeding season. The breeding season at the two areas is different from middle of February to March at Miwon and from late of March to middle of April at Wonju.

Recording was made within 30 cm of a calling male using a DAT digital recorder (PDR 1000) and a condenser microphone (Sennheiser MKH 816P48). During recordings, we also recorded their calling behaviors. The intensity of calls was measured by a Larson-Davis sound level meter (Model 800B) within 30 cm of calling males. After recording, we caught the calling male and then measured the SVL of calling males using vernier calipers within 0.01 cm. The water temperature of calling spots was gained with a digital thermometer (HD8605).

During analyses, we measured call duration (ms), call dominant frequency (Hz), pulse duration (ms), the number of pulses, and pulse interval (ms) on the Kay Electric CSL 4300B (Fig. 1).

Table 1. A-call of *Rana dybowskii* from Miwon (32 individuals, 285 calls) and Wonju (23 individuals, 180 calls).

Area	Call duration (ms)	Call dominant frequency (Hz)	The mumber of pulses of a call	Pulse duration (ms)	Inter-pulse duration (ms)
Miwon	572.67±8.18	1359.11±12.18	5.62±0.07	323.26±7.98	201.44±5.67
Wonju	370.56±6.42	1391.85± 7.50	5.17±0.07	241.87±5.39	128.70±4.03

Pearson product moment correlation test was used for the analysis of the relationship between call characteristics, water temperature, and SVL. In the comparison of Miwon and Wonju A-call we took its value at 9℃ (the middle of the available temperature range) as given by the regression line for the phenotype, and calculated the standard error of this value and the standard deviation for the predicted single value (Sokal and Rohlfs 1981).

RESULTS

Call properties of *Rana dybowskii*

The calls of *R. dybowskii* were classified into A, B, and C types based on the behavioral contexts and physical characteristics on the sonagram. A-call consists of 3-9 pulses which have constant intervals (Fig. 2a, Table 1). Intensity of the calls ranges from 85.9 to 93.9 dB (Mean±SD=88.7±1.3 dB, n=11). A-call is elicited when there are no neighbors within 1 m radius. A male who is calling A-call frequently tries to clasp males and females approaching towards the male.

We recorded 52 calls from 18 individuals. B-call has 4~9 pulses (5.96±0.2, Fig. 2b). Each pulse of the call shows frequency modulation unlike pulses from the A-call. Intervals between pulses are variable and in usual become shorter with the progress of the call. Each pulse of B-call has several harmonic bands. The second and third harmonic bands are most distinctive and show rapid frequency modulation. Call duration of B-call was 568.25±14.02 ms and dominant frequency was 1401.77±23.04 Hz.

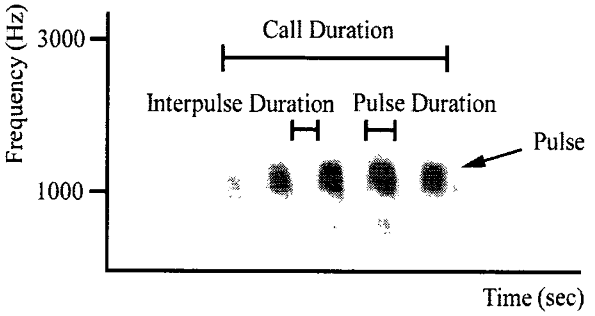

Fig. 1. Call of *R. dybowskii.*

Because *R. dybowskii* forms a lek during breeding season, amplexus between males frequently occurs (Park and Cheong, pers. obs.). At this moment, a male who was amplexed produced a C-call, possibly causing the clasping frog to release his hold. C-call has the shortest call duration (60.47±8.19 ms) among call types and consists of 3~5 pulses. Each pulse has rapid rising phases, but relatively slow falling phases. The dominant frequency of C type call was 618.78±70.12 Hz (10 individuals, 32 calls, Fig. 2c).

Variation of A-call between two regions

The breeding season of *R. dybowskii* in Miwon

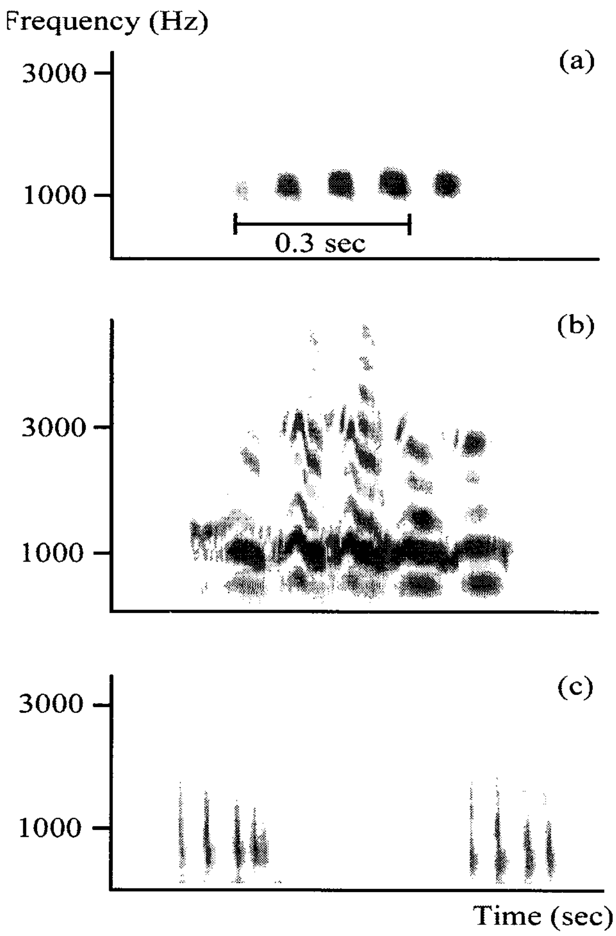

Fig. 2. Call types of *R. dybowskii.* (a) A-call, (b) B-call, (c) C-call.

Table 2. Relationship of A-call parameters of *R. dybowskii* in Miwon and Wonju with water temperature and SVL

Variable (y)	Miwon		Wonju	
	Regression equation	F	Regression equation	F
1. x=Water temperature				
The mumber of pulses of a call	-	1.66n.s	-	0.92n.s
Pulse duration (ms)	-	0.05n.s	y= 308.52- 7.11x	4.05***
Inter-pulse duration (ms)	-	0.82n.s	y= 170.04- 3.71x	2.92**
Call duration (ms)	y=721.18-22.54x	4.76***	y= 478.58-10.83x	5.27***
Dominant frequency (Hz)	y=1240.99+18.17x	2.48*	-	-
2. x=Snout-vent length				
The number of pulses of a call	y=0.82+0.75x	7.28***	-	1.70n.s
Pulse duration (ms)	y= 606.02-45.60x	3.61***	y=-435.61+111.55x	4.08***
Inter-pulse duration (ms)	-	0.15n.s	y=-131.94+ 43.93x	2.19*
Call duration (ms)	y=307.66+41.33x	3.26**	y= 567.55+155.48x	4.81***
Dominant frequency (Hz)	y=1868.90-79.49x	4.26***	-	-

Significance level: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$; n.s. = not significant. 31 individuals, 273 calls (Miwon), 22 individuals. 170 calls (Wonju)

Table 3. Variation of A-calls of *R. dybowskii* from Miwon and Wonju

	Miwon		Wonju		d
	$\hat{y}$	$\hat{S}y$	$\hat{y}$	$\hat{S}y$	
Number of pulses	5.62	0.07	5.17	0.07	3.21***
Pulse duration	323.26	7.98	244.53	18.42	2.98***
Inter-pulse duration	201.44	5.67	128.70	4.03	7.60***
Call duration	518.32	36.25	272.11	21.79	4.24***

Significance level: ***, $p \leq 0.001$. $\hat{y}$: estimated value at 9℃. d: difference coefficients ($d=(\hat{y}_1-\hat{y}_2)/(\hat{S}y_1+\hat{S}y_2)$)

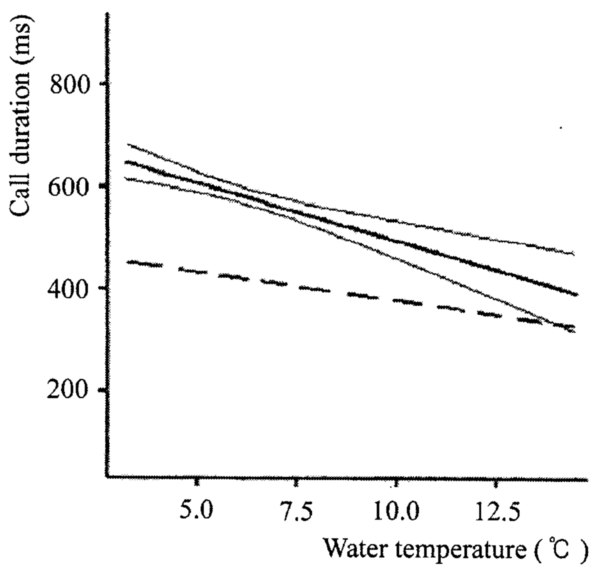

Fig. 3. Variation of A-call of *R. dybowskii* from two regions: Miwon (—); Wonju (---). For *R. dybowskii* from Miwon the 99% confidence limit is also shown.

was about one month earlier than that of Wonju in 1998. Water temperature in Miwon during our call recordings was significantly lower than that of Wonju (Miwon: 6.43±1.70 ℃, Wonju: 9.61±3.10 ℃, t=14.11, $p \leq 0.001$). SVL of the frogs in the Miwon ranged from 6.13 to 6.75 cm (6.41±0.38 cm, n=27), while that in Wonju from 5.98 to 6.22 cm (6.06±0.02 cm, n=13) (F=233.75, $p \leq 0.001$).

In Miwon, as water temperature increased from 4.1℃ to 7.9℃, A type call duration increased but dominant frequency decreased significantly. As SVL of calling male increased from 5.23 cm to 7.80 cm, the number of pulses in a call and call duration increased but dominant frequency decreased significantly (Table 2).

In the comparison of Miwon and Wonju, A type call duration and the factors influencing call duration were significantly different (Table 3, Fig. 3).

DISCUSSION

Calls of *R. dybowskii* are classified into three different calls, A-call, B-call, and C-call. The classification of calls is mainly based on differences in call features. Advertisement call of anurans is most frequently emitted during breeding season and functions to attract females and to advertise calling male's ownership of a territory or calling perch to other males (Wells 1977). The advertisement calls of most frogs and toads consist of a simple whistle, trill, or other type of note repeated many times in succession (Pough *et al.* 1998). A-call of *R. dybowskii* seems to well fit with these characters. Each pulse in a bout of the call is very similar in their features and has constant dominant frequency. These factors make A-call the simplest call among calls of *R. dybowskii.* During our field investigation, females and males approaching towards the male who was calling A-call have been frequently observed.

We, in this report, suggest B-call as an encounter call based on the calling behavior. Encounter call is usually given in closer approach of intruders (Wells 1989). Encounter call of Blanchard's cricket frog (*Acris crepitans blanchardi*) has increased sound pressure level, repetition rate and notes per call (Wagner 1989). Encounter calls may be escalated if the intruder gives encounter calls, and finally any female-attracting components of the call may be abandoned in favor of encounter call if the intruder comes very close. B-call of *R. dybowskii* uniquely has harmonic bands among call types and has relatively high intensity, which is effectively used for the closer communication. Male-male physical confliction was often observed during and after emitting B-call. These call features and our observations during call recording support our suggestion that B-call may function as an encounter call.

The presence of release calls has been known in several species. Release from inappropriate sexual clasping is advantageous because energy and gametes are conserved and the vulnerability of sexually involved couples to predation is minimized (McClelland and Wilczynski 1989). Characteristics of C-call are likely to be well associated with those of release calls of *R. pipiens, R. p. chosenica,* and *R. rugosa* in several aspects. First, the call has short pulse duration and pulse interval. Second, the call does not show any harmonic bands. Third, a bout of call is shortest among calls. Fourth, this call is only obtained during inappropriate clasping such as male and male, or unreceptive female and male. During our field observations, we could only record C-call in the case of male-male amplexus.

A-call properties of a frog were changed by water temperature and SVL. It means that the vocal signal of a frog includes the information about the environmental condition of calling spot and individual property of calling male. This result agrees with many other reports (Nevo and Schneider 1983, Radwan and Schneider 1988). Because A-call has functions to attract mate, it seems that female *R. dybowskii* choose their mates by A-call properties.

The call parameters of frogs in Miwon were different from those in Wonju in call duration, number of pulses, pulse duration and inter-pulse duration significantly (Table 3). In anurans, calls which are distinctive according to the specific areas can be a context for the assortative mating, probably inducing geographic speciation if they are dispersed widely or the distance among population is far (Stebbins and Cohen 1995). There are two reasons of this phenomenon. The first is for the difference of the habitat condition. The more the habitat condition moist, the smaller the size of individual and the higher the fundamental frequency of call in *Bufo viridis* (Nevo and Schneider 1975). The second is because of the difference of physiological state. The cricket frog (*Acris crepitans*) call in New Jersey is different from that of South Dakota in frequency. In this species, the frequency of calls is essential in mate choice because different frequency of calls induce different auditory responses from females. Through auditory response experiments using different call sources, they found that mating calls of males from New Jersey only evoke responses of females who inhabit the same area, but not from South Dakota area. It is because female basilar papilla and amphibian papilla of two regions are different from each other in structure. The female cricket frogs prefer the male's call of the same region (Capranica *et al.* 1973, Capranica 1977).

There is no certain evidence about the reason for geographic variation of vocal signal of *R. dybowskii.* But it is worthy of notice to the difference of breeding season and SVL among the frog of two regions. The breeding season of Miwon was about one month earlier than that of Wonju, and therefore water temperature of Miwon breeding site was significantly lower than that of Wonju ($t=14.109$, $p \leq 0.001$). SVL of the frogs was larger in Miwon than Wonju ($F=233.745$, $p \leq 0.001$). Mentioned earlier, the longer SVL is, the longer call and parameters affecting call duration is. Therefore the major cause of the regional difference may be SVL and water temperature. This result indicates that the vocal signal geographic variation of *R. dybowskii* is a result of adaptation to environmental conditions. It does not mean that there are some physiological differences between the frogs of two regions, however. For the purpose of examination about it, we need experiments about female preference and research of physiological property of sensory system.

ACKNOWLEDGEMENTS

We thank to Hun Chung and Seong-Yong Lee for their helpful field works and to Daesik Park for his valuable comments. This Study was supported by the Basic Research Institute Program, Ministry of Education.

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(*Received May 27, 2000*)