

## A New Species of *Rhacophorus* (Anura: Ranidae) from China

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**Abstract.**— A new brown tree frog species, genus *Rhacophorus*, is described on the basis of seven adult male specimens collected from Cenwanglaoshan Nature Reserve, Guangxi, in southern China. This frog can be distinguished from all other Asian *Rhacophorus* Kuhl and van Hasselt, 1822 by the combination of: skin brown and smooth; Y-shaped cartilage visible dorsally on tips of fingers and toes; outer fingers one-third webbed; distinct dermal ridges present on forearms, above vent, and calcars present on heels; anterior and posterior surface of thighs tangerine in color without distinct dark or light spots; tympanum distinct and large, about 6.6% of SVL; dorsum brown with wide dark cross-shaped mark.

**Keywords.**— Amphibia, Rhacophoridae, *Rhacophorus*, new species.

### Introduction

The genus *Rhacophorus* Kuhl and van Hasselt, 1822, a member of the family Rhacophoridae, contains approximately 60 species (*sensu stricto*) (Frost, 2007) that are distributed in the tropical and temperate zones of East, South, and Southeast Asia. Liem (1970) outlined a conservative definition of the genus (*Rhacophorus sensu stricto*), and while some authors recognize the genus in this sense (Jiang et al., 1987; Fei et al., 1990; Zhao and Adler, 1993; Inger et al., 1999; Malkmus et al., 2002; Frost, 2007; Frost et al., 2006), others have adopted a broader definition (*Rhacophorus sensu lato*) that includes the genus *Polypedates* (Tian and Jiang, 1986; Dubois, 1987, 1992; Fei, 1999; Fei et al., 2005). In a recent review of the Rhacophorinae, a new generic classification was proposed for the Rhacophorinae (Delorme et al., 2005), where some members of *Rhacophorus* were transferred to the new genus *Aquixalus*. This classification was adopted by Frost (2007) and Frost et al. (2006) with some modification. In view of the various interpretations of the Rhacophoridae, the classification of the treefrogs should still be considered unstable (Wilkinson et al., 2002; Matsui and Orlov, 2004), and as stressed by Frost et al. (2006), the boundaries of *Rhacophorus* should be considered tentative.

All Chinese *Rhacophorus* (*sensu lato*) have been found in southern region north to Qinling, with most species distributed in the tropical and subtropical regions. Some new species were recently added to the genus from the regions in and around southern China: *R. hainanus* Zhao et al., 2005 from Hainan, *R. minimus* Rao et al., 2006 from Guangxi, *R. yinggelingensis* Chou et al., 2007 from Hainan, and *R. jarujini* Matsui and

Panha, 2006 from eastern Thailand.

During the survey of the herpetofauna of Cenwanglaoshan Nature Reserve, Guangxi, China, in May 2004 and 2005, seven specimens of a small brown *Rhacophorus* were collected (Fig. 1), which appeared to be distinct from other congeners hitherto known from China (Fei et al., 2005) and nearby countries (Bourret, 1942), including Vietnam (Inger et al., 1999; Orlov et al., 2001), Thailand (Taylor, 1962), Laos (Stuart, 1999), India (Inger and Dutta, 1987), and Burma (Zug et al., 2003). These specimens, which resemble some south-eastern Asia members of the genus, are described below as a new species.

### Materials and Methods

**Morphological data.**— The seven specimens included in the new species were collected by hand in Cenwanglaoshan Nature Reserve, Guangxi, China, in May 2004 and 2005. Five were preserved in 10% buffered formalin, and two were preserved in 70% ethanol. Morphological information of related species used for comparison was obtained from the literature listed below.

**Measurements.**— Sixteen body measurements were made using dial callipers to the nearest 0.1 mm: SVL = snout-vent length; HL = head length from tips of snout to the commissure of the jaws; HW = head width at the commissure of the jaws; SL = snout length from tip of snout to the anterior corner of the eye; INS = internarial space; IOS = interorbital space, i.e., the smallest space between the inner edge of upper eyelid; UEW = width of

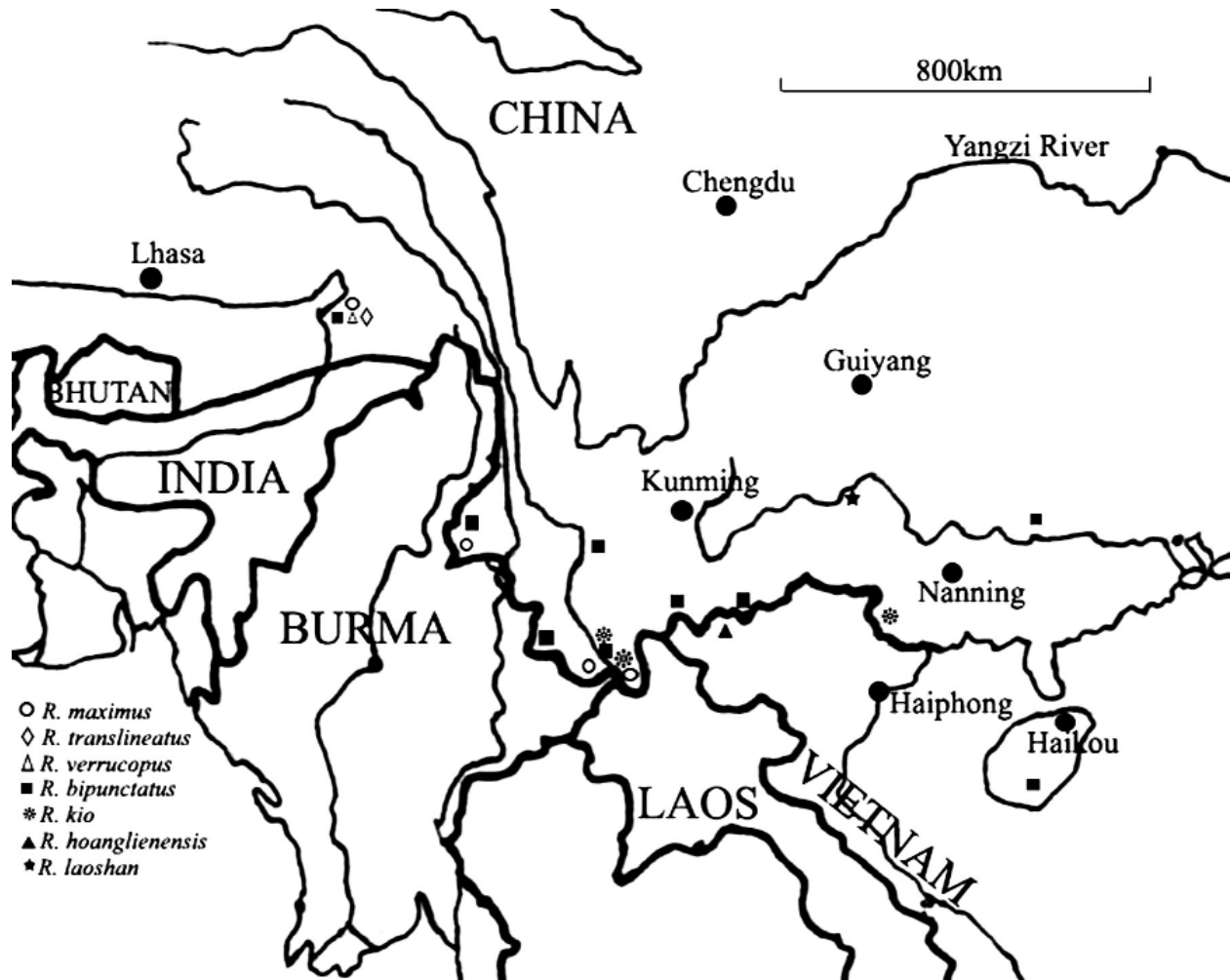


Figure 1. Localities recorded for the six species belonging to the *Rhacophorus reinwardtii* group in China, with the locality recorded for *R. hoanglinensis* in Vietnam.

upper eyelid; ED = diameter of eye; TD = horizontal diameter of tympanum; LAHL = length of lower arm and hand; HAL = hand length; HLL = hindlimb length; TL = tibia length; FTL = length of foot and tarsus; FL = foot length; and TFDD = third-finger disc transverse diameter.

**Analyses of advertisement calls.**— We recorded the advertisement calls of this new species using a Panasonic SV-MP21V recorder (parameter set as 22050Hz, 16 bit, monophone, wav file). Calls were analyzed using Cool Edit Pro V2.1 and BatSound V3.0. Environmental parameters recorded during collection (2010–2340 h) were as follows: air temperature 22°C; moisture 92%.

**Museum acronyms.**— CIB, Chengdu Institute of Biology, Chinese Academy of Sciences; GXNM, Natural History Museum of Guangxi, Nanning, China.

## Taxonomy

### *Rhacophorus laoshan*, new species

Fig. 2

**Holotype.**— Catalog number GXNM 2005081. Adult male collected in Cenwangaoshan Nature Reserve (Guangxi, China) on 19 May 2005 (106° 24' 8.22" E, 24° 29' 1.98" N) at 1389 m altitude by Yunming Mo.

**Paratypes.**— Six adult males, all from the same site as the holotype: CIB 2831k collected on 19 May 2004 by Jianping Jiang, Annemarie Ohler, Yunming Mo, and Feng Xie; GXNM2005079, GXNM2005082, GXNM2005095, CIB2005080, and CIB2005094 collected on 19–20 May 2005 by Yunming Mo.





Figure 2. (A-D) Holotype of *Rhacophorus laoshan* sp. nov.; adult male GXNM2005081.

**Diagnosis.**- This new species *Rhacophorus laoshan* is a small brown treefrog (SVL  $35.1 \pm 1.3$  mm;  $n = 7$ ) that can be distinguished from all other Asian Rhacophoridae by the combination of the following characters: skin brown and smooth; Y-shaped cartilage visible dorsally on tips of fingers and toes; outer two fingers one-third webbed; dermal ridges present on forearm, above vent, and on heel calcaris; anterior and posterior surfaces of thigh tangerine in color and without distinct dark or light spots; tympanum large, about 6.6% of SVL; dorsum brown with wide dark cross.

**Description of holotype.**- Body size small (SVL = 35.4

mm) and moderately elongate. Head moderately compressed, dorsally flat, and wider (HW = 13.9 mm) than long (HL = 13.8 mm). Snout bluntly pointed, projecting, with length (SL = 6.4 mm) longer than horizontal diameter of eye (ED = 4.6 mm). *Canthus rostralis* distinct with loreal region slightly concave. Nostril oval and closer to tip of snout than eye; interorbital space almost flat, and larger (IOS = 4.5 mm) than upper eyelid (UEW = 3.9 mm) and internarial space (INS = 4.0 mm). Tympanum rounded with diameter (TD = 2.3 mm) half that of eye; tympanum-eye distance about half tympanum diameter. Supratympanic fold distinct, present from posterior corner of eye to above and behind insertion of

arm. Vomerine ridges oblique, at an angle of 45° to body axis, and closer to choanae than to each other. Vomerine teeth on tongue pear-shaped, with deep notch on posterior end.

Forearm plus hand about half snout-vent length, with forearm (6.7 mm) shorter than hand (10.9 mm); forearm with distinct dermal ridge from elbow to wrist (Fig. 2); relative length of fingers:  $3 > 4 > 2 > 1$ ; fingers with dermal fringes (Fig. 2); third and fourth fingers with web on basal one-third; tips of all fingers with well-developed disks with distinct circummarginal grooves; discs relatively wide compared to fingers, except for first finger; Y-shaped cartilage easily observable on backs of fingers; subarticular tubercle developed; supernumerary tubercles below base of fingers distinct; inner metacarpal distinct, large, flat, and oval.

Hind limbs rather long, with tibiotarsal articulation reaching middle of eye when leg stretched forward; heels strongly overlapping when limbs folded at right angles to body; tibia (TL 18.0 mm) about half SVL and longer than thigh (12.8 mm) and foot (FL 14.9 mm); relative length of toes:  $4 > 3 = 5 > 2 > 1$ ; tips of all toes with moderately-sized disks (slightly smaller than those of fingers except that of first finger); discs with distinct circummarginal grooves that are relatively wide compared to toe width; Y-shaped cartilage easily observable on backs of toes; web present, half developed, I 1 - 2<sup>1/2</sup> II 1 - 2<sup>1/2</sup> III 1 - 2<sup>1/2</sup> IV 2 - 1 V dermal fringe along toe V distinct; subarticular tubercles prominent on all toes; inner metatarsal tubercle distinct and oval; outer metatarsal tubercle absent.

Dorsum smooth with granules scattered along sides of body and head, along lower mandible, and back of forearm; venter, head, and limbs covered with flat granules; outer edge of forearm and tarsus-metatarsus with granulose ridge; dermal calcars present on heels; granules above vent forming transverse skin fold.

**Color in life.**- Dorsum chocolate brown; broad transverse strip present medially on upper lids and interorbital space; back with broad cross-shaped marking (Fig. 2); limbs with broad transverse stripes: 2 on forearms, 2–3 on carpals and fingers, 3 on thighs and tibiae, and 4–5 on feet and toes; anterior and posterior surfaces of thighs tangerine in colour and usually without distinct dark or light spots; inner surface of tarsus and foot tangerine; belly light gray-brown and without dark spots.

**Male secondary sexual characters.**- Adult males with nuptial pad on the base of first finger; internal subgular vocal sacs present with two elongate openings; linea masculina absent.

**Variation.**- Most variation was found in the appearance

of the wide cross-shaped mark on the dorsum. Usually, this mark was visible except for when the dorsum was more darkly-colored. The snout of some specimens was green, and some specimens had a green spot on the shoulder; ovate yellow spots on the sides of the body sometimes formed a line.

**Etymology.**- The species is named after the locality, i.e., Cenwanglaoshan Natural Preserve in northwestern Guangxi, China, where it was found.

**Measurements.**- Sixteen body measurements are provided in Table 1.

**Habitat and ecological notes.**- This new species was found in a secondary broad-leaf forest with bamboo undergrowth. Dense grass and deciduous leaves covered the ground (Fig. 3). There were almost no perennial streams in the region. During April and May, especially at night after rainfall, males were heard calling loudly in the forest, with six to nine calls making up a chorus. The holotype and paratypes were found on branches and leaves of trees one to three meters from the ground.

**Advertisement calls.**- The analyzed results of the calls by Cool Edit Pro 2.1 and BatSound indicated that calls were emitted every 17–25 seconds and lasted about 3.6–4.6 seconds. The calls had 19–26 notes (6 individuals, 12 calls) (Fig. 4a), with a note interval of 0.171–0.267 seconds (mean  $\pm$  SD:  $0.189 \pm 0.0184$ , 6 individuals, 12 calls, 44 notes). The dominant frequency was 2000 Hz and the second dominant frequency was 4000 Hz (Fig. 4b).

**Comparisons.**- The new species *Rhacophorus laoshan* is most similar in appearance to *R. hoanglienensis* (Orlov et al., 2001) and *R. verrucopus* Huang, 1983. It species can be distinguished from *R. hoanglienensis* by a combination of the following characters: (1) anterior and posterior surfaces of the thighs are orange-red and without distinct dark or light spots (black and white vermiculation is present in *R. hoanglienensis*); (2) body size smaller (SVL  $35.1 \pm 1.3$  mm;  $n = 7$ ) than in *R. hoanglienensis* (SVL 43.2 mm;  $n = 1$ ); (3) tympanum more distinct and larger (TD = 2.3 mm, about 6.6% of SVL) than that of *R. hoanglienensis* (TD = 2.1 mm, about 4.86% of SVL); (4) wide dark cross-shaped mark present on dorsum; (5) venter light gray-brown and without spots (not creamy-white with small dark spots that merge in the distal parts of the fore and hind limbs). Furthermore, the new species emits a call every 17–25 sec. (see above), while *R. hoanglienensis* calls every 3–5 min (Orlov et al., 2001), and white lines running from the supratympanic fold to tip of snout through eyelid and



Table 1. Measurements (in mm) of *Rhacophorus laoshan* sp. nov. Variations (mean  $\pm$  SD) are shown for paratypes and ratios to SVL (%). Abbreviations as used in text.

Character	Holotype	Paratypes (n = 6)	Character	Holotype	Paratypes (n=6)
SVL	35.4	33.2–36.7 (35.1 $\pm$ 1.4)	TD	2.3	2.1–2.7 (2.3 $\pm$ 0.2)
				-6.50%	6.6% (5.9–6.8)
HL	13.8	12.2–13.4 (12.8 $\pm$ 0.4)	LAHL	17.6	16.1–17.7 (17.1 $\pm$ 0.5)
	-39.00%	36.5% (35.2–39.0)		-49.70%	48.7% (47.1–51.2)
HW	13.9	12.8–13.5 (13.1 $\pm$ 0.3)	HAL	10.9	10.4–10.9 (10.6 $\pm$ 0.2)
	-39.30%	37.3% (36.1–39.3)		-30.80%	30.3% (29.4–31.9)
SL	6.4	5.5–6.2 (5.9 $\pm$ 0.3)	HLL	54.7	53.5–56.1 (54.7 $\pm$ 1.1)
	-17.10%	16.7% (15.7–17.1)		-154.50%	156.1% (154.0–169.0)
INS	4	3.6–4 (3.8 $\pm$ 0.1)	TL	18	17.6–18.1 (17.9 $\pm$ 0.2)
	-11.30%	10.9% (10.4–11.7)		-50.80%	51.1% (49.3–53.9)
IOS	4.5	4.2–4.4 (4.3 $\pm$ 0.1)	FTL	23.9	22.4–24.6 (23.7 $\pm$ 0.7)
	-12.70%	12.2% (11.7–13.3)		-67.50%	67.6% (63.1–72.3)
UEW	3.9	3.5–3.9 (3.7 $\pm$ 0.2)	FL	14.9	14.4–15.5 (15.1 $\pm$ 0.4)
	-11.00%	10.6% (10.5–11.0)		-42.10%	43.1% (41.4–45.5)
ED	4.6	4.1–4.7 (4.5 $\pm$ 0.2)	TFDD	2.3	2.2–2.4 (2.3 $\pm$ 0.1)
	-13.00%	12.7% (12.3–13.0)		-6.50%	6.6% (6.3–6.8)

canthal ridge of female of *R. hoanglienensis* (Bain and Truong, 2004). This new species can be distinguished from *R. verrucopus* by the latter lacking vocal sac, head longer than width, outer fingers 1/2 webbed, the dermal ridge on forearm and above vent more weak, and the dorsum without the wide dark cross mark present (Huang, 1983). *Rhacophorus laoshan* can be separated from related species that also have dermal flaps on the forearms, tarsus, vent, or heel as follows. *Rhacophorus laoshan* shows reduced toe webbing, which is more extensive in *R. annamensis*, *R. bipunctatus*, *R. exochopygus*, and *R. reinwardtii* (Inger et al., 1999); complete webbing on the feet is seen in *R. kio*, *R. nigropalmatus*, *R. reinwardtii* (Ohler and Delorme, 2006), *R. maximus* (Liu and Hu, 1961; Fei, 1999), *R. pardalis* (Brown and Alcalá, 1998; Inger, 1954, 1966; Inger and Stuebing, 1997; Malkmus et al., 2002), *R. prominans* (Taylor, 1962; Inger, 1966), and *R. robinsoni* (Taylor, 1962; Inger, 1954) have. The absence of a dark spot in temporal region distinguishes the new species from *R. cyanopunctatus* (Malkmus et al., 2002); and *R. bipunctatus* (Inger et al., 1999).

*Rhacophorus baluensis* can be separated from the new species by being larger (male SVL = 50–55 mm) (Malkmus et al., 2002) and by having dark transverse bars and irregular light or dark blotches on the dorsum (Inger and Stuebing, 1997; Malkmus et al., 2002). *Rhacophorus bimaculatus* (Peters, 1867) is also larger in size (SVL = 65 mm) and has fingers that are almost fully webbed (Fei, 1999). Almost fully-webbed fingers are

also seen in *R. dulitensis* (Taylor, 1962; Inger and Stuebing, 1997). *Rhacophorus gauni* can be separated from the new species by having a conspicuous white spot below the eye (Inger and Stuebing, 1997). The skin of *R. kajau* is leafy green dorsally and usually has minute white spots scattered on the back, head, and exposed surface of the limbs (Inger and Stuebing, 1997; Das, 2007). *Rhacophorus rhodopus* has more developed finger and toe webbing, which is also red in color (Liu and Hu, 1959; Fei, 1999), not grey-brown. *Rhacophorus translineatus* has dark transverse bars on dorsum (Sichuan Institute of Biology [Hu et al., 1977; Fei, 1999]) while *R. laoshan* has a dark wide cross-shaped mark.

The new species can be distinguished from *Rhacophorus appendiculatus* by having irregular low ridges on the back, as well as a narrow flap on the heel (Inger and Stuebing, 1997; Malkmus et al., 2002). *Rhacophorus calcaneus* differs by having oval or round dark brown spots on the dorsum, small enameled white spots, or pinkish dorsolateral bands and a thin black network enclosing large white spots ventrolaterally (Inger et al., 1999). *Rhacophorus verrucosus* has the vomerine teeth absent (not present) and a low conical tubercle on the heel (Inger et al., 1999). *Rhacophorus bisacculus* has no prominent projections in the infra-anal area, but it may have several short, pointed tubercles (Inger et al., 1999). *Rhacophorus naso* has a dorsolateral fold and a skin projection on the tip of the snout (Fei, 1999).

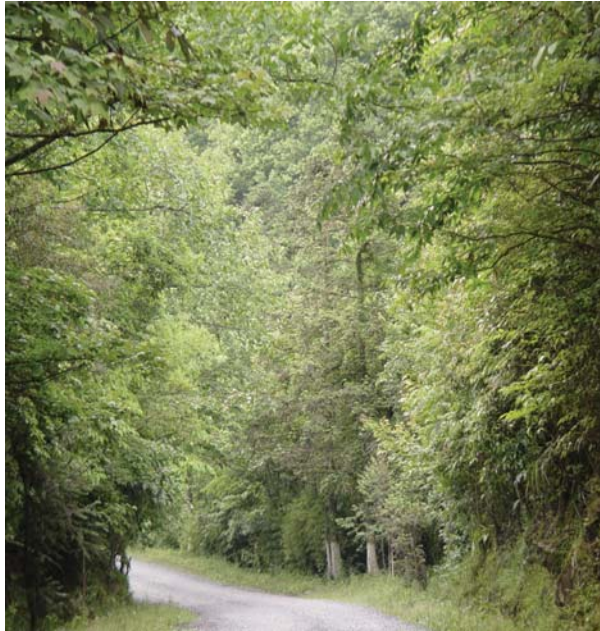


Figure 3. Habitat of *Rhacophorus laoshan* sp. nov.

**Remarks.**— Those *Rhacophorus* with dermal flaps are distributed in the tropical region of southeastern Asia, extending north to the southern slopes of the eastern Himalayas, the Hengduan Mountains, the Yunnan-Guizhou Plateau, and the Nanling Mountains. Within this area, most species are distributed north of 20° N. Of these taxa, *R. bipunctatus*, *R. maximus*, *R. kio*, *R. hoanglienensis*, *R. laoshan*, *R. translineatus*, and *R. verrucopus*, are distributed along the southern border of China (Fig. 1).

*Rhacophorus bipunctatus* (recorded as *R. bimaculatus* by Fei (1999) and Fei et al. (2005) in their list of Chinese amphibians) has the widest Chinese distribution of these seven species (Fig. 1), and is also known from Northeastern India, Myanmar, Thailand, Laos and Vietnam. In China this species occupies the tropical region of the southern slopes of the Yunnan-Guizhou Plateau, the Nanling Mountains, and southern Medog. *Rhacophorus maximus* has and *R. bipunctatus* are known from Yunnan and Tibet. The northern extent of *R. kio* in China is the southern border regions of Yunnan and Guangxi (Ohler and Delorme, 2006; Fei, 1999). *Rhacophorus translineatus* and *R. verrucopus* are found along the southern slope of the eastern Himalayas in Medog, while *R. hoanglienensis* and *R. laoshan* are known from the southern slope of the Yunnan-Guizhou Plateau.

In summary, there are only five *Rhacophorus* species with dermal flaps along the southern slopes of the Yunnan-Guizhou Plateau and the Nanling Mountains: *R. maximus*, *R. kio*, *R. hoanglienensis*, *R. laoshan*, and *R. bipunctatus*. Of these, the new species

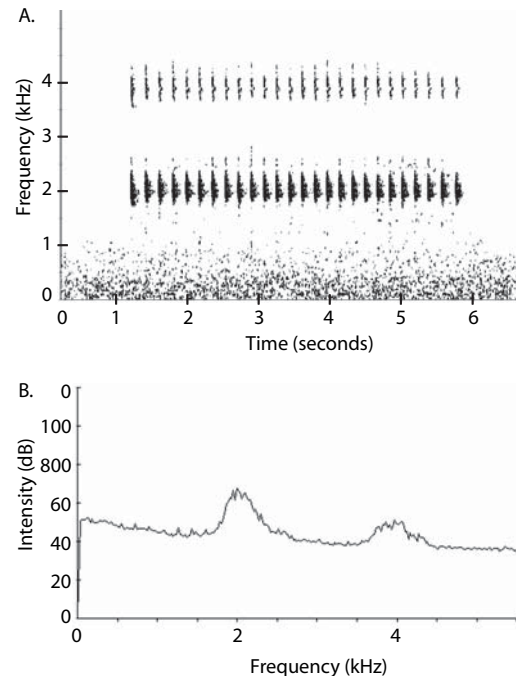


Figure 4. Audio-spectrogram with FFT size 512 (A), and power spectrum (B) of advertisement calls of the new species *Rhacophorus laoshan* (Holotype)

*R. laoshan* is the most northern, *R. bipunctatus* the most eastern and *R. kio* and *R. hoanglienensis* the most southern.

Lastly, only four rhacophorids were recorded in Cenwanglaoshan Nature Reserve (Mo and Xie, 2005), including the new species, suggesting that further surveys of the herpetofauna along the southern slopes of Yunnan-Guizhou Plateau and the Nanling Mountains should be carried out to further explore the little-known biodiversity of this region. Such efforts may elucidate more species or populations of Asian treefrogs or other new species.

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