

A New Species of Brown Frog from Bohai, China

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Abstract.— A new species of brown frog is described from Mt. Culai in Shandong province, China. The new species differs from other Chinese members of the *R. longicrus* group (*R. zhenhaiensis*, *R. chaochiaoensis* and *R. omeimontis*) in that the head is wider than long and female leg is longer than that of the male. Furthermore, the body is larger the web on the inner side of the male fifth toe nearly extends to the toe tip, the dorsal color is reddish-brown, there are no gray or dark bars across the eyes or spots on the back, the labial tooth row formula is frequently 3(2-3)/3, the male tibia is slightly longer than the foot, the dorsal masculine line is absent and the ventral masculine line is weakly developed.

Keywords.— Ranidae, *Rana*, brown frog, new species, China.

Introduction

Brown frogs, also known as wood frogs (Liu, 1946), are a widespread, complex and diverse group in the genus *Rana*. Thirteen brown frogs are known from China, five of which were previously recognized as *R. japonica* (Pope and Boring, 1940). These five species, together called the southern Chinese Brown Frog ($2n = 26$), occur south of the Yangtze River and in Taiwan. The brown frog in Taiwan was revived as *R. longicrus* Stejneger, 1898 and the species on the mainland were subsequently considered to be *R. chaochiaoensis* Liu, 1945, *R. chevronata* Hu and Ye, 1981, *R. omeimontis* Ye and Fei, 1993, *R. zhenhaiensis* Ye, Fei and Matsui, 1995 and *R. japonica* (Fei et al., 1993; Fei et al., 2005; Liu and Hu, 1961; Ye et al., 1995).

The species of southern Chinese brown frog do not overlap in their distributions. *Rana chaochiaoensis* and *R. omeimontis* are more western in distribution, with the former found in Yunnan, Guizhou and Sichuan Provinces, and the latter found in Sichuan and Gansu Provinces, as well as some counties in Guizhou, Hunan and Hubei Provinces (Fei et al., 2005, Li et al., 2005). *R. zhenhaiensis* occurs in eastern and southeastern China, in Anhui, Jiangsu, Zhejiang, Jiangxi, Hunan, Fujian, Guangdong and Guangxi Provinces (Fei et al., 2005; Li et al., 2005). *R. chevronata* is also western in distribution, found only on Mt. Omei (Fei, 1999; Fei et al., 2005; Li et al., 2005). In northern China, *R. japonica*, now replaced by *R. zhenhaiensis* and no *R. japonica* in China (Ye et al., 1995), was recorded formerly at Mt. Culai in Shandong Province and Jixian county in Tianjin (Wang et al., 1997; Wang et al., 1995). The two other species of brown frog found in northern China are *R. chensinensis* and *R. kunyuensis*, found in Shandong peninsula (Li et

al., 2006; Lu and Li, 2002), 500 km away from Mt. Culai.

The present study, part of a project funded by the National Natural Science Foundation of China, was conducted in a region near the Bohai Sea, where the authors collected three species of brown frogs (Li et al., 2005; Li et al., 2006; Lu and Li, 2002). Several specimens resembling *Rana zhenhaiensis* and *R. omeimontis* were collected on Mt. Culai, and were subsequently described as a “species belong to *Rana longicrus* species group in Shandong Province” (Lu et al., 2005). However, after comparing these specimens with representatives of *R. zhenhaiensis* and *R. omeimontis* collected from their type localities and the original descriptions of these species, the frog from Mt. Culai appears to be a distinct and separate species. This new species is here placed within *Rana* as part of the *R. longicrus* group and its relationship to other Chinese members of the group is discussed.

Materials and Methods

From May 2005 to March 2006, surveys were conducted at Mt. Culai, Shandong Province (Fig. 1), and the type localities of *Rana zhenhaiensis* (Caiqiao of Beilun (formerly Zhenhai County), Zhejiang Province) and *R. omeimontis* (Longdong of Mt. Omei, Sichuan Province), where adults, juveniles and tadpoles were collected. Some tadpoles were reared through metamorphosis to confirm their identification, as well as to describe and compare their coloration with respect to the adults, or at least until stages 36–38 for proper description. Specimens were raised in captivity in plastic boxes (260 x 175 x 160 mm) filled with 1.5 L of water. Egg yolk and

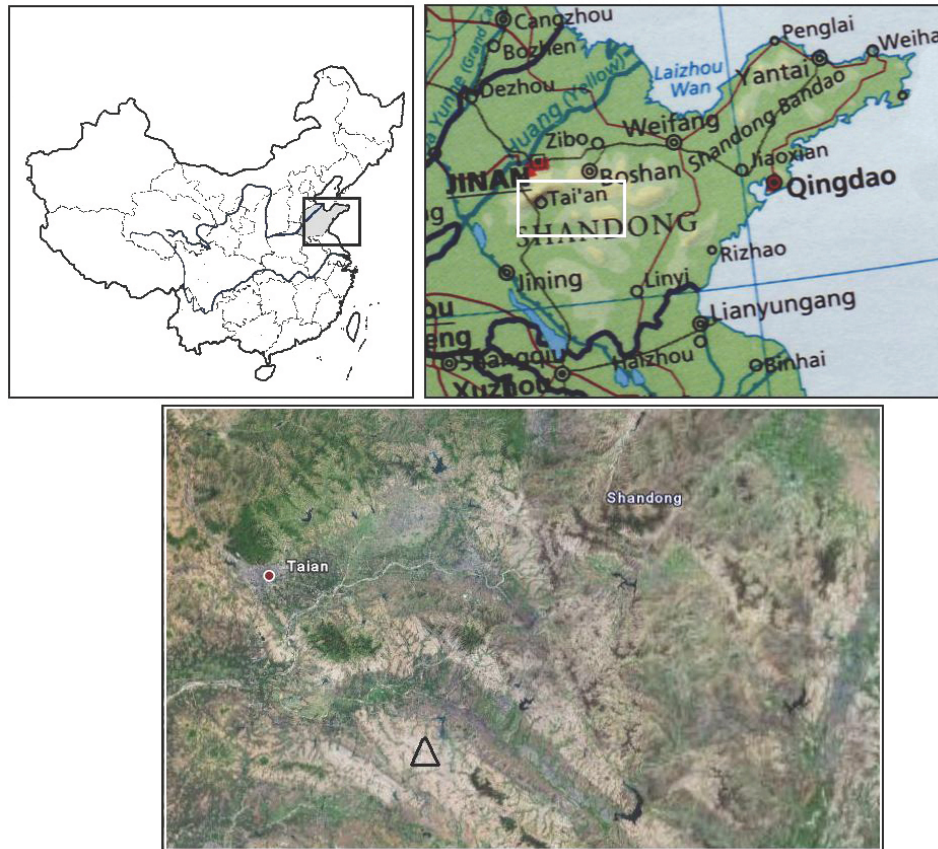


Figure 1. Collection Area in Shandong province, China.
 △: Culai Mountain.

vegetable leaves were regularly provided. Frogs and tadpoles were preserved in 10% formalin and deposited in the collections of Shenyang Normal University.

Measurements were made with digital calipers to the nearest 0.01 mm. Abbreviations are as follows: SVL = snout-vent length; HDL = head length, from tip of snout to rear of jaws; HDW = maximum head width; SNT = snout length, from tip of snout to anterior corner of eye; EYE = diameter of exposed portion of eyeball; IND = internasal distance; IOD = interorbital distance at narrowest point; TMP = horizontal diameter of tympanum; TEY = tympanum-eye distance, from anterior edge of tympanum to posterior corner of eye; FAHL = forearm and hand length; FAW = forearm width; TLL = total length of leg; TIB = tibia length; TFL = tarsus and foot length; FL = foot length, from proximal edge of inner metatarsal tubercle to tip of fourth toe.

All tadpoles were staged according to Gosner (1960). Tadpoles in stage 33, including both reared specimens and those preserved immediately after capture, were measured and used in descriptions. Measurements and terminology follow McDiarmid and Altig (1999). The labial tooth row formula follows those outlined by McDiarmid and Altig (1999) and Dubois (Li, 2006).

All measurements were taken with a digital caliper (to the nearest 0.01 mm) under a stereomicroscope, except for total length, which was measured with the caliper directly. Photographs were taken with Nikon D100 and Sony 717 digital cameras.

Data from *Rana zhenhaiensis* and *R. omeimontis* were taken from their original descriptions and from additional specimens collected from their respective type localities and other localities stored in Chengdu Institute of Biology (CIB) and Museum of Natural History of Shenyang Normal University (SYNU).

Taxonomy

Rana culaiensis, new species

(Figs. 2–3)

Holotype and type locality.- An adult male, Field number YT050526007, collected by Lu Yuyan on 27 May 2005 from Mt. Culai (117° 18' E, 36° 02' N), Taian City, Shandong province, China (Fig. 1), at 900 m elevation.

Paratypes.- An adult female, Field number YT050526005, other information as for the holotype.

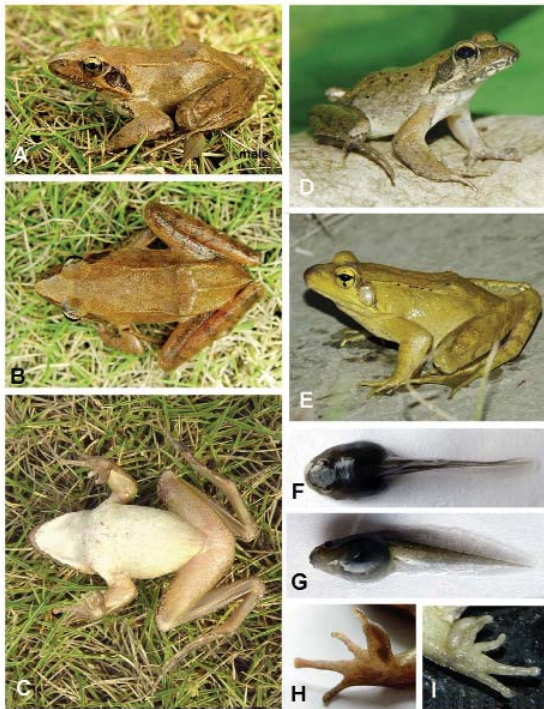


Figure 2. Holotype of *Rana culaiensis*, sp. nov. and its allied species from type localities. (A) Dorsal, (B) Lateral and (C) Ventral view of *R. culaiensis*, (D) Lateral view of *R. zhenhaiensis*, (E) Lateral view of *R. omeimontis*, (F) Dorsal and (G) Lateral view of tadpole of *R. culaiensis* at stage 33, (H) Palmar view of hand in *R. culaiensis*, (I) Palmar view of hand in *R. zhenhaiensis*.

Five males, Field number YT050526001-004, YT050526006, collected by Lu Yuyan on 27 May 2005 from Mt. Culai (36° 02~03' N, 117° 17~18' E, Taian City, Shandong province, China, at 690–900 m elevation.

Tadpoles.— Other information as for the holotype.

Diagnosis and comparisons.— This new species is superficially similar to *Rana zhenhaiensis*, but it can be distinguished by the following characters: 1) average snout-vent length larger in adult males (53.6 mm) and females (62.0 mm); 2) head length slightly less than head width; 3) toes 3/4 webbed, with web on inner side of male fifth toe nearly extending to tip; 4) dorsal color reddish brown, without gray or dark bar across eyes or spots on back; 5) dorsal masculine line absent and ventral masculine line weakly developed; 6) male tibia slightly longer than foot; 7) labial tooth row formula frequently 3(2-3)/3. Furthermore, with respect to similar brown frogs in China, the female leg of *R. culaiensis* is longer than the male leg.

On the other hand, this new species can be separated from all other southern Chinese brown frogs on the basis

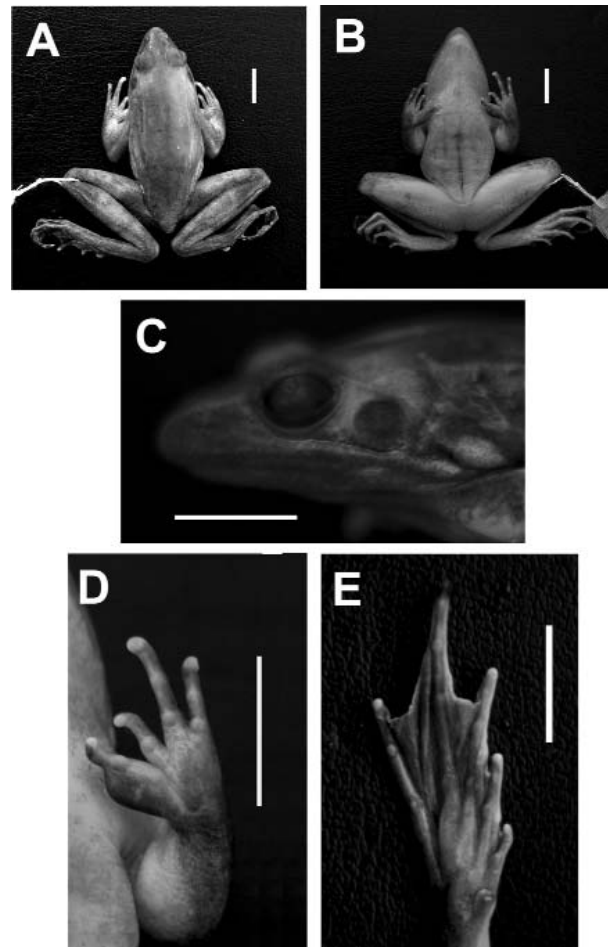


Figure 3. Holotype of *Rana culaiensis*, sp. nov. (A) Dorsal view, (B) Ventral view, (C) Lateral view of head, (D) Palmar view of hand, (E) Tarsal view of Foot. Scale bar = 10 mm.

of a head that is wider than long and a female leg that is longer than that of the male. When comparing *Rana culaiensis* to other southern Chinese brown frogs in the *R. longicrus* group, it appears to be a very well-defined species with conspicuous diagnostic features (Fig. 4; Table 2) that easily separate it from the superficially similar *R. zhenhaiensis*, *R. omeimontis* and *R. chaochiaoensis*.

From *R. zhenhaiensis* in having larger males and females, longer female legs, a more well-developed web on inner side of male toe 5 (ill developed in *R. zhenhaiensis*), an indistinct ventral masculine line (on both sides in *R. zhenhaiensis*) and a different breeding season (from March to April in *R. culaiensis* and January to March in *R. zhenhaiensis*).

From *R. omeimontis* in having slightly curved dorso-lateral fold (straight in *R. omeimontis*), relatively longer female legs, an indistinct ventral masculine line (on both sides in *R. omeimontis*), a larger TMP:EYE ratio (0.66) and different breeding seasons (July to

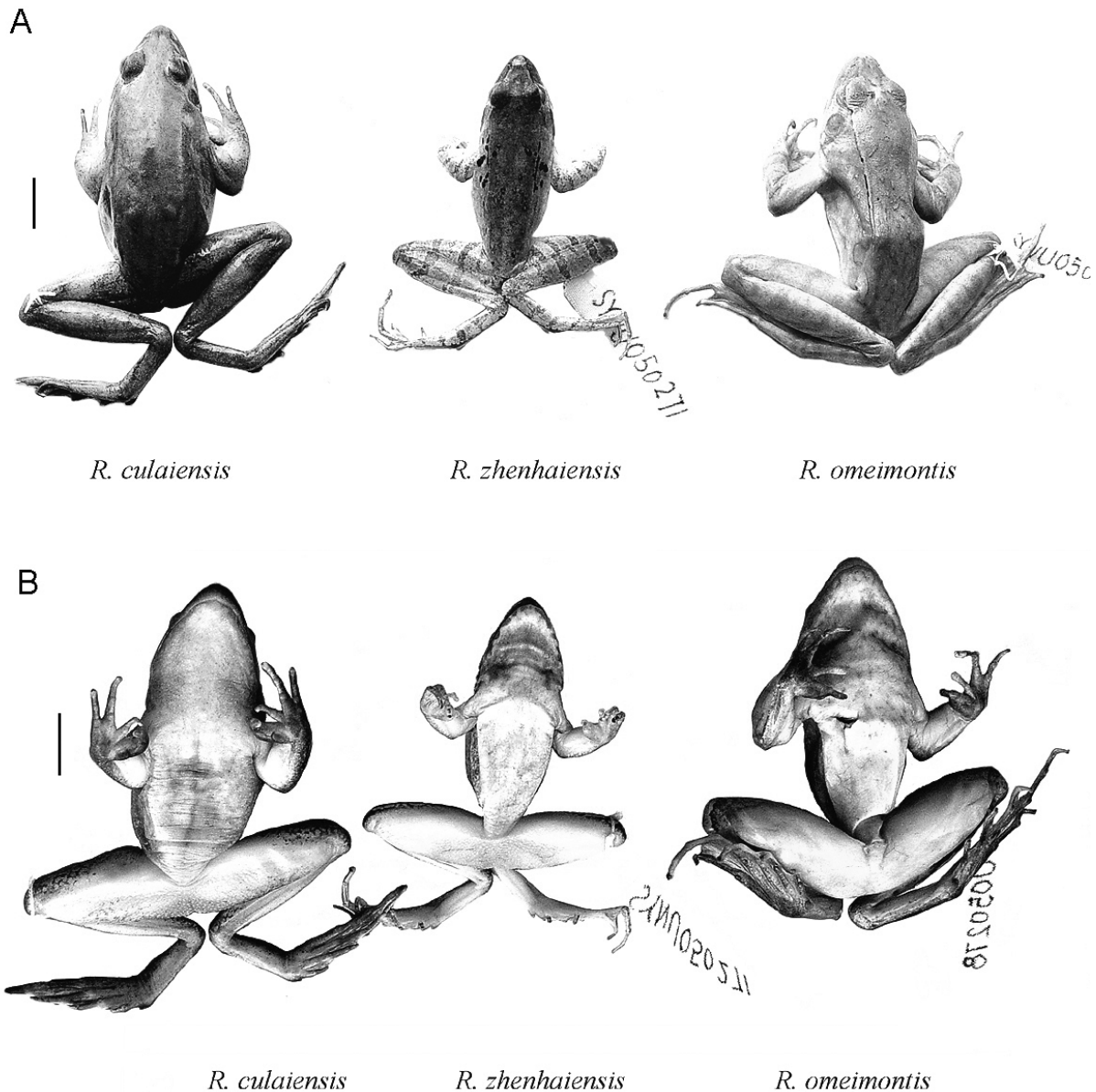


Figure 4. *Rana culaiensis*, sp. nov. and its allied species from their type localities. (A) dorsal view of male and (B) ventral view of male (scale bar = 10 mm).

October in *R. omeimontis*).

From *R. chaochiaoensis* in having slightly curved dorsolateral fold, relatively longer female legs (legs of subequal length in both sexes of *R. chaochiaoensis*), an indistinct ventral masculine line, a yellowish-white female venter (reddish-orange in *R. chaochiaoensis*), three rows of teeth on the tadpole lower lip (four rows in *R. chaochiaoensis*) and a different breeding season (April to May in *R. chaochiaoensis*, with some breeding seen as late as August).

In distribution, *Rana culaiensis* is allopatric to its related species. It is a common case in the brown frogs

in China, such as *Rana chevronta* which only found located at a narrow area in Mt. Omei (Fei et al., 2005) and *R. kunyuensis*, which is closed to *R. amurensis* and located in Mt. Kunyu only (Che et al., 2007; Li et al., 2005).

Description of holotype.- An adult female with SVL 62.0 mm; HDW slightly wider than HDL and head strongly depressed; snout rounded (more so on projection beyond lower jaw) and SNT slightly longer than EYE; *canthus rostralis* distinct, loreal region slightly oblique; nostril slightly closer to tip of snout; IND wider

Table 1. Measurements (mm) of allotype and paratypes of *Rana culaiensis*, sp. nov.

Characters	Allotype (♀) (n=1)	Paratypes (♂) (n=5)	Characters	Allotype (♀) (n=1)	Paratypes (♂) (n=5)
SVL	62.04	48.47~59.06* 53.57±4.29**	TMP	4.78 7.70%	3.41~4.32 3.69±0.37 6.89%
HDL	18.45 29.74%***	14.63~17.37 16.01±1.22 29.89%	FAHL	28.25 45.54%	21.52~26.62 23.71±1.96 44.26%
HDW	19.99 32.22%	15.43~18.24 16.72±1.25 31.22%	FAW	4.96 7.99%	5.53~7.18 6.31±1.00 11.78%
SNT	9.41 15.17%	7.05~8.24 7.64±0.65 14.27%	TLL	121.29 195.50%	82.78~108.12 95.92±10.84 179.05%
IND	5.48 8.83%	4.39~5.44 5.07±0.45 9.46%	TIB	39.35 63.43%	26.29~34.99 30.80±3.68 57.49%
IOD	4.51 7.27%	3.45~3.91 3.64±0.19 6.80%	TFL	53.12 85.62%	38.99~48.89 44.25±4.10 82.59%
UEW	4.07 6.56%	3.12~3.97 3.51±0.36 6.55%	FL	36.95 59.56%	28.62~33.65 30.29±3.18 56.54%
EYE	7.62 12.28%	5.13~6.73 5.91±0.62 11.03%			

Note: * size range, ** mean ± SD (n = 5), *** % SVL.

than IOD and IOD wider than upper eyelid width; tympanum large, round, TMP two-thirds diameter of EYE and separated from eye (TEY) by one-third of TMP; vomerine teeth developed in slightly oblique groups between and behind choanae, with groups narrowly separated in “\ /” shape; tongue deeply notched and with papillae.

FAHL less than half of SVL; fingers obtuse with relative length of fingers II < IV < I < III; subarticular tubercles prominent; three metacarpal tubercles distinct (inner one large and outer two separated at bases). TLL relatively long; tibio-tarsal joint reaching nostril, making TIB about 57.8% of SVL; heels overlapping when limbs folded at right angles to body; TIB slightly longer than FL; toes also obtuse with tips similar to those of fingers, toes 3/4 webbed with subarticular tubercles well developed; web of inner side of male fifth toe nearly extending to tip of toe; inner metatarsal tubercle oval, outer metatarsal tubercle weakly developed.

Skin rather smooth above, with few warts; glandu-

lar dorsolateral fold running along each side of body behind eye to insertion of hind leg and slightly curved to temporal fold above tympanum; temporal fold distinctly curving posteriorly from above tympanum to large triangular gray patch behind eye; ventral surface of body smooth except for posterior and median surfaces of femora, which are covered with coarse granular glands (small granules).

Measurement of holotype.- SVL 56.8 mm; HDL 17.15 mm; HDW 17.9 mm; SNT 7.8 mm; IND 5.32 mm; IOD 3.51 mm; UED 3.97 mm; EYE 6.26 mm; TMP 3.69 mm; FAHL 23.63 mm; FAW 7.6 mm; TLL 106.17 mm; TIB 34.2 mm; TFL 47.91 mm; FL 33.7 mm.

Coloration of holotype in life (in preservative).- Dorsum evenly reddish or yellowish-brown (gray), without gray or dark interorbital bars; stripe on upper lip dark brown with white blotches, extending from tip of snout to venter of eye, joining with dark reddish-brown

(yellow) stripe running to behind arm insertion; lower lip with brown speckles; rictal glands brown (yellow); limbs gray dorsally with four and five dark cross-bars on thigh and tibia, respectively; sides of body light yellow. Dorsolateral fold pale brown (yellow); throat and belly creamy-yellow (white with pale gray nebulous marks); triangular patch gray to somewhat black (gray with tympanum dark brown); metacarpal tubercles and nuptial pad dark brown (black).

Description of paratypes.- The paratypes, six adult specimens, one female (YT050526005) and five males (YT050526001-004, YT050526006) approximate the holotype in almost all pertinent details. The measurements of paratypes summarized in Table 1. However, there are some minor differences between paratypes and the holotype as follows:

MALE PARATYPES.- One male specimen with small tubercles on sides of body covered with black. And the following characters of male paratypes as secondary sexual characters: smaller than female with FAW much thickened; male with strong nuptial pads on the inner-dorsal side of first fingers, extended to figure tip and separated at metacarpus; no vocal sacs; lineae musculinae indistinct ventrally and absent dorsally; TLL is shorter than the female TLL.

FEMALE PARATYPE.- The female specimen with light jacinth spots ventrally in life (pale gray flecks in preservative).

Tadpoles.- The body ovoid in dorsal profile, pear-like in lateral profile; darkly colored in life (tail more grey in preservative). In stage 33, body length 16 mm, tail length 34 mm, length of hind limb 9 mm; snout rounded, eye dorsolateral, nostril slightly closer to snout tip; spiraculum small, on left side of body and with no free tube; vent dextral, tube of vent continuous with ventral caudal fin; dorsal fin rising from base of tail. Tail height about half of body length with apex obtuse; musculation weakly developed on pointed tip; mouth anteroventral, with row of labial papillae on lower lip and mouth corner (papillae of lower lip regularly arranged); corner of mouth with several additional papillae; labial tooth row formula frequently 3(2-3)/3, length of tooth row long, horny beak weak and narrow.

Habitat.- During field work at Mt. Culai of Shandong province in 2005 and 2006, we surveyed the Mt. Culai and the nearby mountains and collected the frogs described here as a new species in a forest brook (alt. 630–900m) covered with gramineous grass following the breeding season. The tadpoles in stage 28–34 were

collected on 27 May 2005. No eggs were found at that time, suggesting that the breeding season for this species was in March and April.

Etymology.- *Rana culaiensis* is so named as it is apparently restricted to Mt. Culai of Shandong province, East China.

Taxonomic account.- As Liu (1946) indicated, “among the Chinese amphibian the woodfrog group presents a problem most difficult to solve. Great confusion exists in the literature, as there has been no satisfactory comparative study of preserved museum specimens of different species, and no careful investigation in the fields.” In some species groups, the frogs are quite conservative in their morphology and very difficult to separate (Liu and Hu, 1961; Lu and Li, 2002; Tanaka et al., 1996; Xie et al., 2000), as is also the case for the many species of Eurasian brown frogs (Kim et al., 2002). Although much progress has been made in the systematics of these species, many brown frogs are still difficult to identify and some species may yet remain undescribed (Che, 2007; Lu and Li, 2005).

The brown frogs of the *Rana longicrus* group (formerly treated as the *Rana japonica* group) included four species (*Rana zhenhaiensis*, *R. chaochiaensis*, *R. omeimontis*, and *R. chevronta*) in the mainland of the southern China and one species (*Rana longicrus*) in Taiwan (Fei et al., 2005; Xie et al., 2000). These frogs once classified as *R. japonica* by Pope and Boring (1940), The species-level status of *R. chaochiaensis*, *R. chevronta* and *R. longicrus* has never been questioned, but some researchers still treat *R. omeimontis* and *R. zhenhaiensis* as *R. japonica* (Zhao et al., 2000), even though Xie et al. (2000) provided significant morphological, ecological, cytological and morphometrical support to verify the status of all five species. Well-supported phylogenetic analyses have also been provided (Che, 2007; Jiang and Zhou, 2001; Yang et al., 2001). The cluster tree provided by Xie et al. (2000) illustrates a close relationship between *R. omeimontis* and *R. chaochiaensis*, as well as a close relationship between *R. zhenhaiensis* and *R. chevronta*.

The Culai frogs once reported as new province record under *Rana japonica* (Wang et al. 1997), but *R. japonica* was replaced by *R. zhenhaiensis* by Ye, Fei and Matsui (1995). Here we treated it as a new species with some difference from other related species in the group and it maybe close to *R. zhenhaiensis* and *omeimontis* (Fig. 4; Table 2). As allopatric to its congeners, it shows the same case of as *Rana chevronta* and *R. kunyuensis*.

Material examined.-

Rana chaochoensis from CIB (n = 70). (males)

Table 2. Comparisons between *Rana culaiensis* and its allies.*

Species	<i>R. chaochiaoensis</i>	<i>R. omeimontis</i>	<i>R. zhenhaiensis</i>	<i>R. culaiensis</i>
Chromosome	2n = 26	2n = 26	2n = 26	2n = 26*
SVL (mm)	♂52.7, ♀52.9	♂58.5, ♀61.0	♂46.1, ♀48.9	♂53.6, ♀62.0
Head shape	HL > BW	BL > BW	BL > BW	BL < BW
Dorsolateral fold	Straight	Straight	Slightly curved	Slightly curved
IOD:UED	smaller	smaller	smaller	larger
TMP: EYE	3-Feb	5-Mar	3-Feb	3-Feb
IOD:TMP	0.68	0.75	0.73	0.98
TIB:FL	1.05	1.03	0.96	1.03
HL/SVL (%)	♂181.1 ♀183.5	♂196.7 ♀182.4	♂178.8 ♀171.5	♂178.8 ♀195.5
Male's web of inner side of toe 5	Ill developed	Well developed	Ill developed	Well developed
Color of female ventral side	Reddish Orange	Yellowish white	Yellowish white	Yellowish white
Nuptial pad	Extend to the figure tip, no separated at metacarpus	Extend to the figure tip, separated at metacarpus	Extend to the figure tip, slightly separated at metacarpus	Extend to the figure tip, separated at metacarpus
Masculine line	Both	Both	Both	Ventral only
Denticle formula on the lower lip of tadpole	4 lines	3 lines	3 lines	3 lines
Tadpoles live through winter or no	No or yes	Yes	No	No
Breeding season	Apr.–May, some to Aug.	Sep.–Oct.	Jan.–Mar.	Mar.–Apr.
Elevation range	2000–2000m	1500 m	10–1400 m	630–900 m

* data of *Rana chaochiaoensis*, *R. omeimontis* and *R. zhenhaiensis* cited from Xie et al. (2000).

CIB37841, CIB37842, CIB37847, CIB37850, CIB37851, CIB37852, CIB37855, CIB37857, CIB37859, CIB37866, CIB37867, CIB37870, CIB37873, CIB37877; (females) CIB378853, CIB37860, CIB37862, CIB37869, CIB37874, CIB37876 and CIB84495 from China, Sichuan Province, Zhaojue County (as Chaocho formerly, type locality). (males) CIB37643, CIB37683, CIB37703; (females) CIB37641, CIB37642, CIB37644, CIB37681, CIB37699, CIB37700 and CIB37707 from China, Sichuan Province, Yuexi, Mianning, and Yanyuan Counties. (males) CIB37712, CIB37713, CIB37715, CIB37723, CIB37731, CIB37734, CIB37735, CIB37747, CIB37748, CIB37754, CIB37755, CIB37756, CIB37758, CIB37760; (females) CIB37720, CIB37721, CIB37724, CIB37725, CIB37773 and CIB37777 from China, Guizhou Province, Weining County. (males) CIB37796, CIB37799, CIB37798, CIB37801, CIB37802, CIB37803, CIB37804, CIB37805, CIB37806, (females)

CIB37786, CIB37787, CIB37788, CIB37790, CIB37792, CIB37793 and CIB37830 from China, Yunnan Province, Kunming City. (males): CIB37840, CIB37839 and (female) CIB37838 from China, Yunnan Province, Lijiang County.

Rana chevronta from CIB (n = 1): (male) CIB65I0028 from China, Sichuan Province, Mt. Omei (type locality).

Rana omeimontis from SYNU (n = 8): (males) SYNU050274, SYNU050275, SYNU050278, SYNU06080522, SYNU06080523; (females) SYNU050276, SYNU050277 and SYNU050279 from China, Sichuan Province, Omei Mt (type locality).

Rana zhenhaiensis from SYNU (n = 18): (males) SYNU050267, SYNU050268, SYNU050271, SYNU06020126, SYNU06040129, SYNU06040130, SYNU06040131, SYNU06040132, SYNU06040133, SYNU06040134, SYNU06040135; (females) SYNU050269, SYNU050270, SYNU050272,

SYNU050273, SYNU06020127, SYNU06020128 and SYNU06040136 . China, Zhejiang Province, Beilun region (formerly Zhenhai county, type locality).

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