

<http://dx.doi.org/10.11646/zootaxa.3737.4.5>

<http://zoobank.org/urn:lsid:zoobank.org:pub:2499D127-1B3F-4868-A737-1274827D6806>

A new species of *Leptolalax* (Anura: Megophryidae) from the highest mountain in Indochina

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Abstract

We describe a new species of *Leptolalax* from northern Vietnam. *Leptolalax botsfordi* **sp. nov.** is distinguished from its congeners by a combination of (1) supra-axillary and ventrolateral glands present; (2) dark brownish red ventral surface with white speckling; (3) medium body size for the genus (29.1–32.6 mm in 7 adult males, 30.0–31.8 mm in 2 females); (4) black markings on the flanks absent; (5) toes with rudimentary webbing and weak lateral fringing; (6) large pectoral glands (1.1–1.9 mm; 4–6% SVL) and femoral glands (2.4–4.3 mm; 7–14% SVL); and (7) an advertisement call with a dominant frequency of 2.6–3.2 kHz (at 14.0° C). At present, the new species is known only from upper montane forest between 2,795–2,815 m elevation on Mount Fansipan, Hoang Lien National Park. To our knowledge, *Leptolalax botsfordi* **sp. nov.** occurs at higher elevations than any other species in the genus. If *L. botsfordi* **sp. nov.** is truly restricted to a narrow, high-elevation band, it is likely to be particularly vulnerable to the effects of climate change. The new species also faces the immediate threat of habitat degradation and pollution due to tourist activity.

Key words: Bioacoustics, Mount Fansipan, *Leptolalax botsfordi* **sp. nov.**, Southeast Asia

Introduction

The genus *Leptolalax* Dubois 1983 is an increasingly diverse group of small-bodied frogs (SVL < 60 mm), currently comprising 37 species (Dehling 2013; Frost 2013). Frogs in the genus inhabit the forest floor and rocky streams in hilly evergreen forest throughout Southeast Asia, southern China and northeastern India (Frost 2013). Over a third of all *Leptolalax* species have been described in the last five years, a result of both increased survey efforts in the region and the addition of acoustic and molecular data in delineating species boundaries in the genus. Here we describe a new species of *Leptolalax* from upper montane forest on Mount Fansipan in northern Vietnam, the highest mountain in Indochina. The new species occurs at higher elevations than other *Leptolalax* species known from Mount Fansipan and surrounds (Bourret 1937; Ohler *et al.* 2000) and is distinguished from all congeners on the basis of morphological and bioacoustic differences.

Materials and methods

We recorded morphological data from specimens fixed in 10% formalin and then stored in 70% ethanol. Specimens were deposited at the Vietnam National Museum of Nature (VNMN) and the Australian Museum (AMS). Morphometric data were taken (to the nearest 0.1 mm) with digital callipers. Measurements include snout-vent length (SVL); head length from tip of snout to rear of jaws (HDL); head width at commissure of jaws (HDW); snout length from tip of snout to anterior corner of eye (SNT); diameter of exposed portion of eyeball (EYE);

interorbital distance (IOD); horizontal diameter of tympanum (TMP); distance from anterior edge of tympanum to posterior corner of eye (TEY); tibia length with hindlimb flexed (TIB); manus length from tip of third digit to proximal edge of inner palmar tubercle (ML); and pes length from tip of fourth toe to proximal edge of the inner metatarsal tubercle (PL). We use a traditional formula for finger numbering rather than one based on homology (eg. Alberch & Gale 1985). Sex was determined by the presence of internal vocal sac openings and gonadal inspection. Mass was recorded in life (to the nearest 0.1 g), using Pesola scales. Geographic coordinates were obtained using a Garmin GPSMAP 60CSx GPS receiver and recorded in datum WGS 84. We obtained comparative morphological data from museum specimens of *Leptolalax* and photographs of these specimens in life (Appendix I) and from the literature: *L. aereus* (Rowley *et al.* 2010a), *L. alpinis* (Fei *et al.* 1991, 2009, 2010), *L. applebyi* (Rowley & Cao 2009), *L. araycai* (Matsui 1997), *L. bourreti* (Dubois 1983; Ohler *et al.* 2011), *L. bidoupensis* (Rowley *et al.* 2011), *L. croceus* (Rowley *et al.* 2010b), *L. dringi* (Dubois 1987; Inger *et al.* 1995), *L. eos* (Ohler *et al.* 2011), *L. firthi* (Rowley *et al.* 2012), *L. fritimmiensis* (Dehling & Matsui 2013), *L. fuliginosus* (Matsui 2006), *L. gracilis* (Günther 1872; Inger & Stuebing 2005; Dehling 2012), *L. hamidi* (Matsui 1997), *L. heteropus* (Boulenger 1900), *L. kajangensis* (Grismer *et al.* 2004), *L. kecil* (Matsui *et al.* 2009), *L. khasiorum* (Das *et al.* 2010), *L. lateralis* (Anderson 1871; Humtsoe *et al.* 2008), *L. liui* (Fei *et al.* 1991, 2009, 2010), *L. maurus* (Inger *et al.* 1997), *L. melanoleucus* (Matsui 2006), *L. melicus* (Rowley *et al.* 2010c), *L. minimus* (Taylor 1962; Ohler *et al.* 2011), *L. nahangensis* (Lathrop *et al.* 1998), *L. nokrekensis* (Mathew & Sen 2010), *L. nyx* (Ohler *et al.* 2011), *L. oshanensis* (Liu 1950; Fei *et al.* 2009, 2010), *L. pelodytoides* (Boulenger 1893, 1908; Ohler *et al.* 2011), *L. pictus* (Malkmus 1992; Malkmus *et al.* 2002), *L. platycephalus* (Dehling 2012), *L. pluvialis* (Ohler *et al.* 2000, 2011), *L. solus* (Matsui 2006), *L. sungi* (Lathrop *et al.* 1998), *L. tamdil* (Sengupta *et al.* 2010), *L. tuberosus* (Inger *et al.* 1999; Rowley *et al.* 2010b), *L. ventripunctatus* (Fei *et al.* 1991, 2009, 2010). Due to the degree of undiagnosed diversity within the genus, where available, we relied on examination of topotypic material and/or original species descriptions.



FIGURE 1. Type locality of *Leptolalax botsfordi* sp. nov. on Mount Fansipan, northern Vietnam.

Advertisement calls were recorded with an Edirol R-09HR WAVE/MP3 Recorder (96 kHz sampling rate and 24-bit encoding) with a Røde NTG-2 condenser shotgun microphone. Calls were recorded at a distance of approximately 0.2 m and ambient temperatures at the calling site were taken immediately after recordings using a Kestrel 3500 hand-held weather meter. Calls were analysed with Raven Pro 1.3[®] software (<http://www.birds.cornell.edu/raven>). Audiospectrograms in figures were calculated with fast-Fourier transform (FFT) of 512 points, 50% overlap using Hanning windows. The units of a call, a note or a pulse were defined according to Duellman (1970), except that we define a single call as vocalisations produced during a single expiration (Brown & Richards 2008). Temporal and spectral parameters of calls were measured using the definitions of Cocroft & Ryan (1995), except for fundamental frequency, where the definition of Duellman (1970) was used. For each call recording, we measured the call duration (ms), intercall interval (ms), number of notes per call, internote interval (ms) and dominant frequency (kHz). Comparative advertisement call characters for *Leptolalax* species were taken from references, with advertisement calls known for 21 of the 37 known species of *Leptolalax* (Matsui 1997; Jiang *et al.* 2002; Malkmus *et al.* 2002; Xu *et al.* 2005; Matsui 2006; Matsui *et al.* 2009; Rowley & Cao 2009; Rowley *et al.* 2010a, 2010b, 2010c, 2011, 2012; Sukumaran *et al.* 2010; Dehling & Matsui 2013). To maintain consistency and facilitate meaningful comparisons, we have used the terminology defined above to compare calls, regardless of terms used in these references.

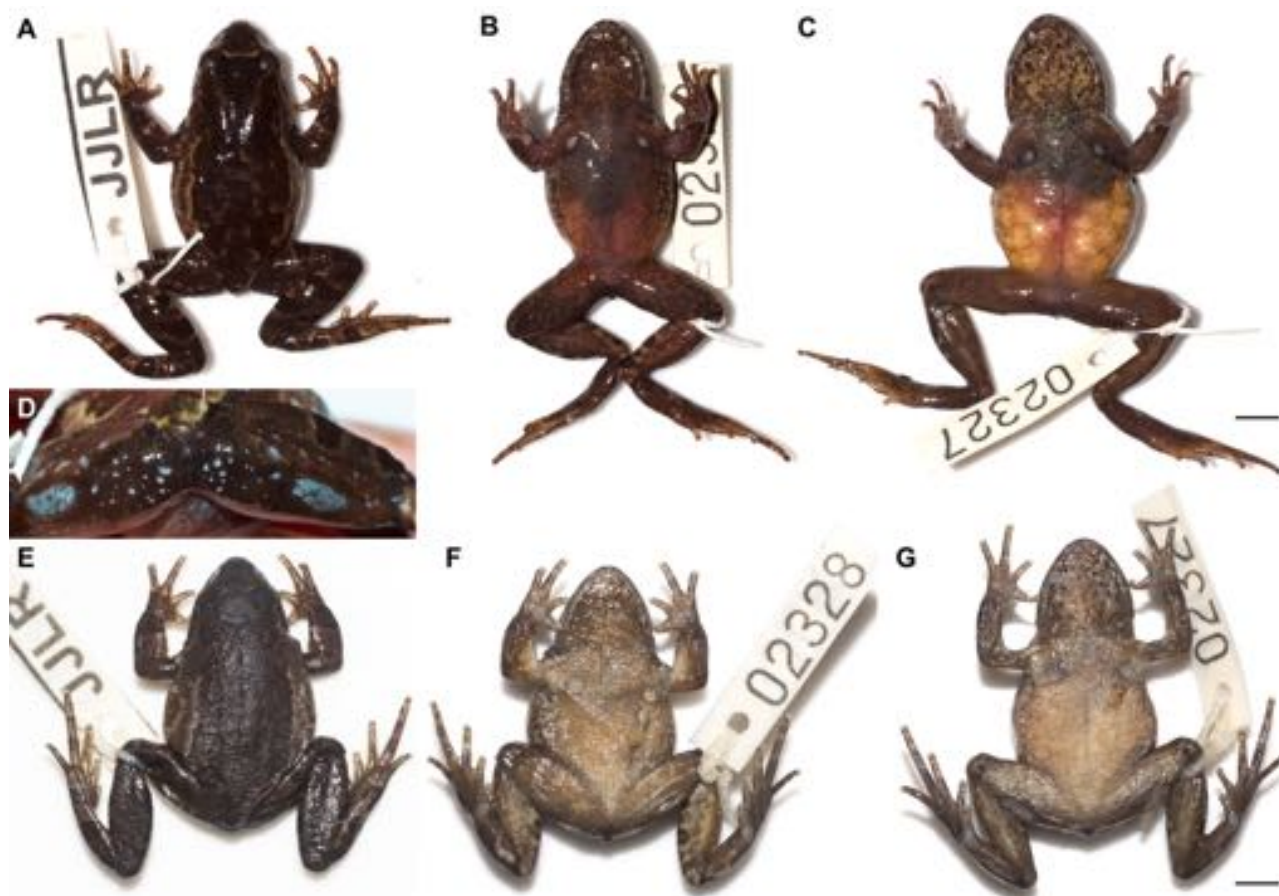


FIGURE 2. *Leptolalax botsfordi* sp. nov. (A) dorsal and (B) ventral view of adult male holotype VNMN 03682 in life, (C) ventral view of gravid female paratype AMS R 176540 in life, (D) posterior view of adult male holotype VNMN 03682 in life, showing large femoral glands in (not to scale), (E) dorsal and (F) ventral view of adult male holotype VNMN 03682 in preservative, and (G) ventral view of adult female paratype AMS R 176540 in preservative. Scale bars = 5 mm.

Leptotalax botsfordi sp. nov.

Holotype: VNMN 03682, adult male, calling under leaf litter, 0.2 m from small trickle of water running through mossy rocks to a 1 m-wide cascading stream in upper montane forests on Mount Fansipan, Hoang Lien National Park, Lao Cai Province, Vietnam (22.3135° N, 103.7652° E, 2,815 m elevation; Figure 1). Collected at 19:35 h on 10 June 2012 by Jodi J. L. Rowley, Vinh Quang Dau, Sang Van Pham, Tu Van Tran, Su A Hang, and Di A Hoang.

Paratypes: AMS R 176540 (adult female) climbing into mud hole in seep at 19:55 h, and AMS R 176534–176538 (five adult males), collected at same geographic locality and date as holotype. AMS R 176541 (adult female) and AMS R 176539 (adult male), collected on 11 June 2012, adjacent to a 2 m-wide, swift cascading stream in upper montane forest on Mount Fansipan, Hoang Lien Son National Park, Lao Cai Province, Vietnam at 22.3139° N 103.7654° E, 2,795 m elevation). All specimens were collected by Jodi J. L. Rowley, Vinh Quang Dau, Sang Van Pham, Tu Van Tran, Su A Hang, and Di A Hoang.

Etymology: Specific epithet is a patronym honouring Christopher Botsford, for his support of amphibian biodiversity conservation research and scientific capacity building in Asia.

Diagnosis: Assigned to the genus *Leptotalax* on the basis of the following characters: small (< ~60 mm SVL) size, rounded finger tips, the presence of an elevated inner palmar tubercle not continuous to the thumb, presence of macroglands on body (including supra-axillary, pectoral, femoral and ventrolateral glands), the absence of vomerine teeth, the presence of tubercles on eyelids, and anterior tip of snout with pale vertical bar (Dubois 1983; Lathrop *et al.* 1998; Delorme *et al.* 2006). *Leptotalax botsfordi* sp. nov. is distinguished from its congeners by a combination of (1) supra-axillary and ventrolateral glands present; (2) dark brownish red ventral surface with white speckling; (3) medium SVL for the genus (29.1–32.6 mm in 7 adult males, 30.0–31.8 mm in 2 females); (4) black markings on the flanks absent; (5) toes with rudimentary webbing and weak lateral fringing; (6) large pectoral glands (1.1–1.9 mm; 4–6% SVL) and femoral glands (2.4–4.3 mm; 7–14% SVL); and (7) an advertisement call with a dominant frequency of 2.6–3.2 kHz (at 14.0 °C).



FIGURE 3. Adult female *Leptotalax botsfordi* sp. nov. AMS R 176540 in life. Note metallic copper flecks, particularly along snout, supratympanic fold and flanks.

Description of holotype: Head width equal to head length; snout rounded in dorsal view and rounded in profile, projecting slightly beyond margin of the lower jaw; nostril equidistant between snout and eye; canthus rostralis indistinct, gently rounded; lores slightly concave; vertical pupil; eye diameter smaller than snout length; tympanum barely distinct, round, diameter smaller than that of the eye; tympanic rim elevated relative to skin of temporal region on ventral side only; vomerine teeth absent; pineal ocellus absent; vocal sac openings slit-like, located posterolaterally on floor of mouth in close proximity to the margins of the mandible; tongue long, wide, with broad, shallow notch at posterior tip; supratympanic ridge distinct, running from eye towards axillary gland, with raised tubercles. Tips of fingers rounded, slightly swollen; relative finger lengths $I < II < IV < III$; nuptial pad absent; subarticular tubercles absent; a large, round inner palmar tubercle distinctly separated from small, laterally compressed outer palmar tubercle; finger webbing and dermal fringes absent (Figure 5A). Tips of toes like fingers; relative toe length $I < II < V < III < IV$; subarticular tubercles absent, replaced by dermal ridges; large, oval inner metatarsal tubercle present, outer metatarsal tubercle absent; toe webbing rudimentary; narrow lateral fringes on all toes (Figure 5B). Tibia 46% of snout-vent length; tibiotarsal articulation reaches to middle of eye. Skin on dorsum shagreened; ventral skin smooth; pectoral gland large, oval, 1.5 mm diameter; femoral gland large, oval, approximately 3.4 mm diameter, on posteroventral surface of thigh, closer to knee than to vent; supra-axillary gland raised, 1.8 mm diameter. Ventrolateral glands just visible as small white dots forming an incomplete line anteriorly, barely visible in preservative.



FIGURE 4. *Leptotalax botsfordi* sp. nov. in life. (A) adult male holotype VNMN 03682; (B) adult female AMS R 176540; (C) adult male AMS R 176539; (D) female AMS R 176541. Note robust arms of males.



FIGURE 5. Palmar surface of (A) left hand and (B) right foot of adult male holotype *Leptolalax botsfordi* **sp. nov.** VNMN 03682. Scale bar = 1 mm.

Colour of holotype in life (Figure 2A–B): Dorsal surface dark brown with gold edging dorsolaterally; gold interorbital bar; very faint transverse dark brown bars on the dorsal surface of the thighs, tibia, tarsus, lower arms, fingers and toes. Supratympanic ridge and vertical bar at anterior tip of snout metallic copper. Flanks marbled metallic gold and pale brown. Ventral surfaces slightly transparent reddish brown with faint paler flecks most obvious on slightly darker throat and thighs. Supra-axillary gland white edged in pale copper; pectoral glands opaque white; femoral glands white (Figure 2D). Iris dark brownish gold with densely-packed minute, black reticulations throughout. Iris periphery lined with black. Sclera white.

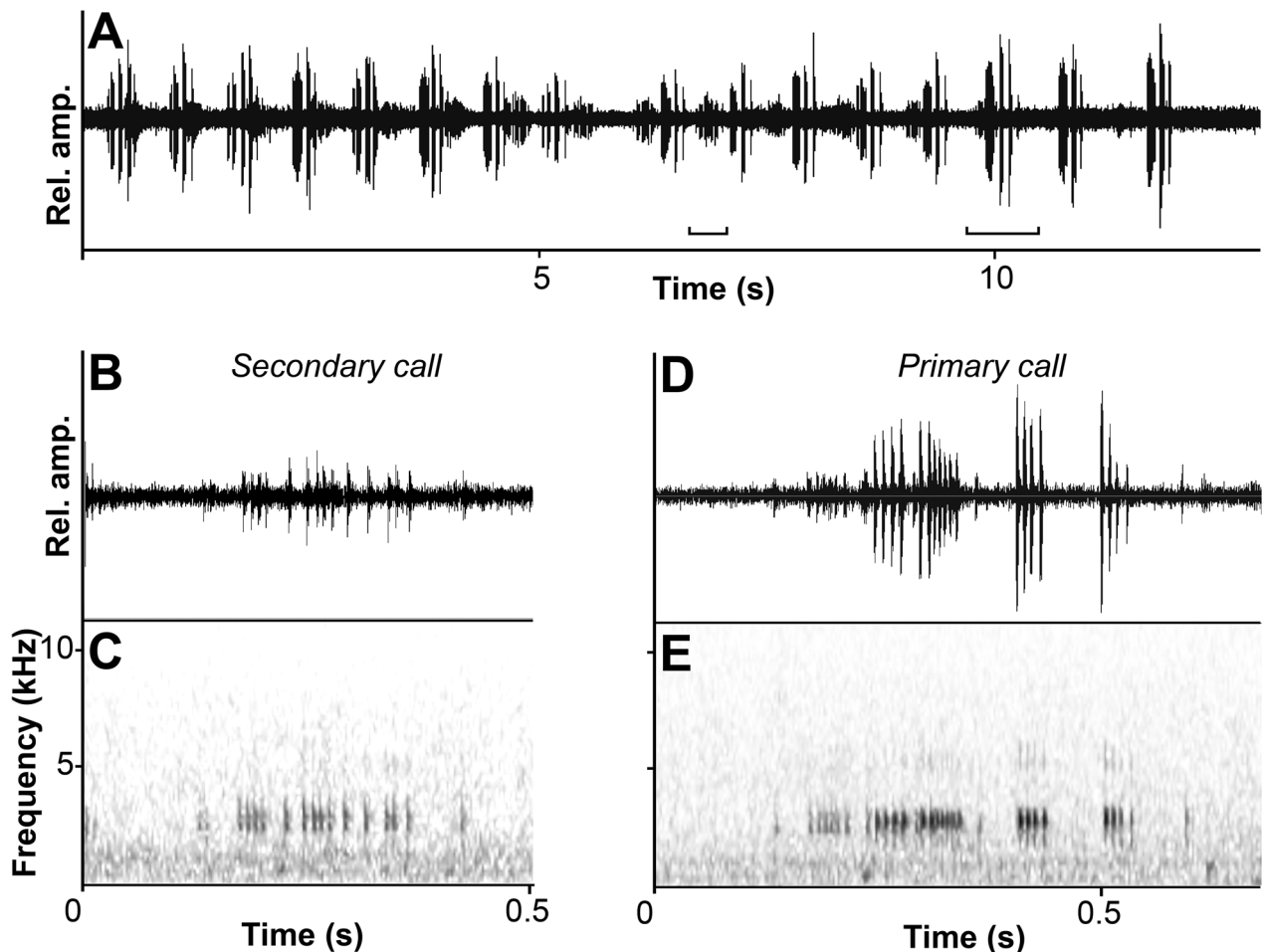


FIGURE 6. Advertisement call of *Leptolalax botsfordi* sp. nov. holotype VNMN 03682 (A) 14 s waveform of relative amplitude (Rel. amp.) over time for 16 “primary” calls, (B) waveform and (C) corresponding spectrogram of single representative “secondary” call expanded from first section shown in A, and (D) waveform and (E) corresponding spectrogram of single representative “primary” call expanded from second section shown in A; all recorded at an ambient air temperature of 14.0 °C.

Colour of holotype in preservative (Figure 2E–F): Dorsum dark brown; flanks marbled with paler brown; interorbital bar and dorsal surface of fingers and toes paler brown. Ventral surface of chest, belly, and thighs slightly mottled brown; throat dark brown speckled with white; arms and tibiotarsus mottled dark brown and cream. Macrogranules creamy white.

Measurements: Holotype: SVL 29.1, HDL 10.1, HDW 10.1, SNT 4.0, EYE 3.4, IOD 3.4, TMP 1.7, TEY 1.2, TIB 13.4, ML 7.4, PL 14.3, weight 2.4 g



FIGURE 7. Habitat of *Leptolalax botsfordi* **sp. nov.** (A) View of Mount Fansipan and surrounding mountains, Lao Cai Province, Vietnam. (B) Microhabitat of calling male *L. botsfordi* **sp. nov.** at ~2,800 m elevation.

TABLE 1. Measurements (mm) of *Leptolalax botsfordi* sp. nov. Abbreviations defined in text.

	VNMN 03682*	AMS R 176534	AMS R 176535	AMS R 176536	AMS R 176537	AMS R 176538	AMS R 176539	AMS R 176540	AMS R 176541
SEX	Male	Male	Male	Male	Male	Male	Male	Female	Female
SVL	29.1	32.6	29.5	30.4	28.7	28.8	30.5	31.8	30.0
HDL	10.1	10.7	10.4	10.1	10.3	10.8	10.5	11.0	10.2
HDW	10.1	10.9	10.4	10.6	11.0	10.3	10.6	10.5	10.3
SNT	4.0	4.2	3.8	4.1	4.2	4.3	4.1	4.7	4.3
EYE	3.4	2.9	3.2	3.4	3.0	2.8	2.8	3.5	2.9
IOD	3.4	-	3.0	3.2	3.5	3.1	3.3	3.0	3.4
TMP	1.7	1.8	1.4	1.8	1.5	1.8	2.0	1.8	1.7
TEY	1.2	1.6	1.6	-	1.6	1.4	1.5	1.2	1.5
TIB	13.4	14.2	13.5	14.3	13.6	14.5	15.0	14.1	15.1
EN	1.9	2.2	1.9	2.0	2.1	2.4	2.3	2.1	2.1
IN	3.1	2.9	2.8	2.9	2.8	3.0	2.8	3.0	3.0
NS	1.9	2.0	2.1	2.1	1.9	2.0	1.9	2.2	2.1
ML	7.4	7.5	6.9	7.9	7.3	7.4	8.3	7.8	8.1
PL	14.3	14.4	13.2	14.1	14.8	14.3	15.2	14.5	15.0
HDL/HDW	1.00	0.99	1.00	0.95	0.94	1.04	0.99	1.05	0.99
HDL/SVL	0.35	0.33	0.35	0.33	0.36	0.37	0.34	0.35	0.34
TIB/SVL	0.46	0.44	0.46	0.47	0.47	0.50	0.49	0.44	0.50
Weight in life (g)	2.4	2.8	2.2	2.5	2.4	2.7	2.3	3.0	2.3

Variation: Measurements of the type series are shown in Table 1 and representative photographs of paratypes are shown in Figures 2–4. Specimens vary only slightly in the colour and extent of marbling on the dorsum; male AMS R 176537 was slightly paler pinkish brown in life. Males have more robust forearms than females (compare males in figures 4A and 4C with females in figures 4B and 4D).

Advertisement call: Call descriptions are based on the calls of the holotype, recorded at 14.0 °C ambient temperature. Calls were of two distinct types (Figure 6), the more frequent and higher amplitude clicking calls referred to here as ‘primary calls’, and low amplitude ‘rasps’ referred to as ‘secondary calls’. Primary calls were an average of 267 ms in duration and consistently comprised of three notes (Table 2, Figure 6). Calls were highly amplitude modulated, with amplitude peaking at the start of each note. Notes contained a variable number of pulses repeated at a highly variable rate (average ~86 pulses/s, range ~40–146 pulses/s). The number of pulses decreased from note one to note three, with notes two and three almost always containing 4 and 2 pulses respectively. The dominant frequency of the primary call was 2.6–3.2 kHz, and harmonics were weakly present at approximately 5.0–5.5 kHz. A fundamental frequency was not visible. Primary calls were repeated at a rate of approximately 1.3 calls per second, and had an average intercall interval of 0.5 s. Secondary calls were an average of 299 ms in duration and consisted of a single note with 14–19 irregularly-spaced pulses (Table 2, Figure 6). Secondary calls were of less amplitude than primary calls, and not strongly amplitude modulated. The dominant frequency of the secondary call was slightly higher than the primary call (2.8–3.4 kHz). Due to background noise in the recording, full analysis of secondary calls was not possible. To the human ear, the advertisement call of *L. botsfordi* sp. nov. is a weak chirping, similar to an orthopteran.

Ecology: All specimens of *Leptolalax botsfordi* sp. nov. were found in upper montane forest between 2,795–2,815 m elevation on Mount Fansipan (Figure 7A). The climate of Mount Fansipan is almost temperate, with an average temperature of about 15 °C (range -3–20 °C), with frequent freezing in the coldest months (Nguyen & Harder 1996). The mountain has 3,500 mm of rain and 2–3 snow days per year, and no dry months (Nguyen & Harder 1996; Nguyen *et al.* 2000). In addition to the heavy rainfall, fog is common and evaporation rates low (Nguyen 1998). Several males were heard faintly calling under leaf litter adjacent to a small stream (Figure 7B) and females were located whilst moving towards calling males. The species was very difficult to locate, even when

calling. During surveys conducted within the same week at lower elevations (1,355–2,240 m) on Mount Fansipan and surrounding habitat in Hoang Lien National Park and Sa Pa, District, *Leptotalax botsfordi* **sp. nov.** was not detected, although the two other *Leptotalax* species known from Mount Fansipan and surrounds (Bourret 1937; Ohler *et al.* 2000), *L. bourreti* and *L. pluvialis*, were common.

Distribution: *Leptotalax botsfordi* **sp. nov.** is only known from relatively near the summit of Mount Fansipan, northern Vietnam. Mount Fansipan is the highest point in Indochina (3,143 m), and part of the Hoang Lien Son Mountain Range, which extends south from the Ailao Shan mountains in China, the south-easternmost extension of the Himalayan chain. The actual distribution of the new species is unknown but may extend along the range northwest through Lao Cai and Lai Chai provinces and into Yunnan Province in China, or southeast further into Vietnam. However, there are only a handful of small, isolated areas along the range above 2,700 m until approximately 250 km further north in Yunnan Province.

TABLE 2. Measurements of advertisement call parameters for adult male holotype (VNMN 03682) of *Leptotalax botsfordi* **sp. nov.** recorded at 14.0 °C ambient temperature. Parameter values are given as means (and ranges).

	Primary call	Secondary call
Number of calls measured	10	5
Call duration (ms)	267 (239–303)	229 (194–283)
Call repetition rate (calls/s)	1.3	
Intercall interval (ms)	536 (406–1028)	
Notes/call	3	1
Dominant frequency (kHz)	3.0 (2.6–3.2)	3.1 (2.8–3.4)
Pulses/note		
Note 1	10.8 (7–15)	15.8 (14–19)
Note 2	4.1 (4–5)	
Note 3	2.4 (1–4)	

Comparisons: In having supra-axillary and ventrolateral glands, *L. botsfordi* **sp. nov.** differs from the southern species *L. arayai*, *L. dringi*, *L. fuliginosus*, *L. fritinniensis*, *L. gracilis*, *L. hamidi*, *L. heterops*, *L. kajangensis*, *L. kecil*, *L. maurus*, *L. melanoleucus*, *L. pictus* and *L. solus* (all of which are considered to belong in the subgenus *Leptotalax*; Delorme, Dubois, Grosjean, and Ohler, 2006).

Leptotalax botsfordi **sp. nov.** is distinguished from all species in the genus except for *L. applebyi*, *L. bidoupenensis*, and *L. melicus* by having a dark brownish red ventral surface with white speckling (*L. aereus*, *L. alpinus*, *L. arayai*, *L. bourreti*, *L. dringi*, *L. firthi*, *L. fuliginosus*, *L. fritinniensis*, *L. gracilis*, *L. hamidi*, *L. khasiorum*, *L. lateralis*, *L. liui*, *L. minimus*, *L. nahangensis*, *L. nokrekensis*, *L. oshanensis*, *L. pelodytoides*, *L. pictus*, *L. playcephalus*, *L. solus*, *L. sungi*, *L. tamdil* and *L. tuberosus* have mostly white or pale grey/brown venters, with or without dark spots or mottling; *L. croceus* has a bright orange belly; *L. pluvialis* has a dirty white/grey venter with dark brown/grey marbling, and uniform pale dirty white/grey throat with pale speckling only around the margins; *L. melanoleucus* and *L. ventripunctatus* display large patches of distinct brown/black and white marbling, *L. heterops* has a grey venter, speckled with black; *L. maurus* has a black or dark grey brown venter, with indistinct small light areas, and *L. kecil* has a uniformly dark venter with large, dark orange pectoral glands).

From the three species with dark reddish brown ventral surfaces, *L. botsfordi* **sp. nov.** differs by having a SVL of 29.1–32.6 mm in 7 adult males, 30.0–31.8 mm in 2 females (*L. applebyi* males 19.6–22.3 mm, females 21.7–25.9 mm; *L. bidoupenensis* males 23.6–24.6 mm, females 29.2–29.4 mm; *L. melicus* males 19.5–22.7 mm), and in having only faint white spotting (versus dense white spotting or marbling on the belly). Body size also distinguishes the new species from the smaller *L. alpinus* (26.3 mm), *L. croceus* (males 22.2–27.3 mm), *L. kecil* (males 19.3–20.5 mm, female 25 mm), *L. khasiorum* (24.5–27.3 mm), and *L. pluvialis* (males 21.3–22.3 mm), and the larger *L. bourreti* (male 36.2 mm), *L. eos* (males 33.1–34.7 mm), *L. gracilis* (males 34.3–39.0 mm, females 42.4–49.3 mm), *L. kajangensis* (males 34–35 mm), *L. nahangensis* (male 40.8 mm), *L. platycephalus* (male 35.1, female 46 mm), *L. sungi* (males 48.3–52.7 mm, females 56.7–58.9), and *L. tamdil* (male 32.3 mm, female 31.8 mm).

An absence of black markings on the flanks further distinguishes the new species from *L. alpinus*, *L. applebyi*,

L. bidoupensis, *L. bourreti*, *L. oshanensis*, *L. fuliginosus*, *L. frittianensis*, *L. gracilis*, *L. hamidi*, *L. heteropus*, *L. kecil*, *L. melanoleucus*, *L. melicus*, *L. nokrekensis*, and *L. pelodytoides*. In having toes with rudimentary webbing and weak lateral fringing, *L. botsfordi* **sp. nov.** can also be readily differentiated from *L. alpinus*, *L. firthi*, and *L. liui*, which have wide lateral fringing on toes, and from *L. pelodytoides*, which has more extensive webbing and wide lateral fringes between toes. In addition, *Leptolalax botsfordi* **sp. nov.** has large pectoral glands (1.1–1.9 mm; 4–6% SVL) and femoral glands (2.4–4.3 mm; 7–14% SVL). The femoral glands in particular are the most prominent of all *Leptolalax* species measured by us (see Appendix I; femoral glands 2–8% SVL).

The advertisement call of *L. botsfordi* **sp. nov.** is unique among congeners with known calls. In having a call with a dominant frequency of 2.6–3.2 kHz (at 14.0 °C), *L. botsfordi* differs from all but *L. bidoupensis*, *L. croceus*, *L. fuliginosus*, *L. gracilis*, *L. heteropus*, *L. kecil*, *L. melanoleucus*, *L. melicus*, *L. solus* and *L. tuberosus* (*L. aereus* 6.2–7.9 kHz at 22.4–25.7 °C; *L. alpinus* ~6.7 kHz at 16 °C; *L. applebyi* 4.0–4.3 kHz at 21.5 °C; *L. arayai* 5.4–5.8 kHz at 17.4 °C; *L. dringi* 7–7.5 kHz at 24.3 °C; *L. hamidi* 7.0 kHz at 22.9 °C; *L. liui* 5.3 kHz; *L. oshanensis* 4.4–4.6 kHz, 14 °C, recorded from c. 40 km from type locality of *L. oshanensis*; *L. pictus* 6.8–7.2 at 19–22 °C; *L. firthi* 5.6–6.4 kHz at 18.3–21.2; *L. fritinniensis* 7.3–9.2 at 24.3–24.9 °C). Although frequency can vary with temperature, differences among species of the scale reported here are unlikely to be attributed to temperature alone. From *L. bidoupensis*, the call differs in having variable note types and in the number of notes per call (1 or 3 versus 6–9), from *L. croceus* in the number of notes per call (1 or 3 versus 4–5), *L. fuliginosus* in the number of notes per call (1 or 3 versus 6–9), *L. gracilis* in the number of notes per call (1 or 3 versus 3–4), *L. heteropus* in the number of notes per call (1 or 3 versus 6–9), *L. kecil* in having variable note types and in the number of notes per call (1 or 3 versus 4), *L. melanoleucus* in the number of notes per call (1 or 3 versus 3–4), *L. melicus* in the number of notes per call (1 or 3 versus 4–11), *L. solus* in the number of notes per call (1 or 3 versus 4–8) and *L. tuberosus* in the number of notes per call (1 or 3 versus 1 single pulsed call). In lacking strong frequency modulation, the call of *L. botsfordi* **sp. nov.** differs from *L. dringi* and *L. hamidi*.

Discussion

To our knowledge, *Leptolalax botsfordi* **sp. nov.** is known from higher elevations (2,795–2,815 m elevation) than any other species in the genus. The only other species of *Leptolalax* recorded from over 2,100 m elevation is *L. alpinus*, with a type locality at 2,400 m in Yunnan Province, China (Fei *et al.* 1991), and a reported elevation range from 1,150–2,400 m (Fei *et al.* 2010). Compared to other *Leptolalax* species, *L. botsfordi* is particularly ‘robust’, and at the time of capture, males of the species had large fat bodies visible through the skin (so much so that we initially thought they were gravid females). These fat reserves may be an adaptation to a shorter activity period and lower food availability at higher altitudes (Fitzpatrick 1976; Chen *et al.* 2013).

Leptolalax botsfordi **sp. nov.** and sympatric amphibians including the newly discovered *Oreolalax sterlingae* Nguyen *et al.* 2013, known only from the same stream as *L. botsfordi* **sp. nov.** on Mount Fansipan, face the immediate threat of habitat degradation and pollution. Mount Fansipan is heavily impacted upon by tourists, and the habitat of *L. botsfordi* **sp. nov.** is noticeably polluted with garbage and runoff from toilets near the stream. In addition, if *L. botsfordi* **sp. nov.** is truly restricted to a narrow, high-elevation band, the species is likely to be particularly vulnerable to climate change, as tropical montane cloud forests are predicted to be exceptionally vulnerable to climate change (Foster 2001).

Acknowledgements

The Vietnamese Ministry of Agriculture and Rural Development and staff at Hoang Lien National Park kindly facilitated surveys and issued permissions (Permit numbers 19/BTTNVN and A13041165/A72-P2). Pham Van Sang, Tran Van Tu, Hang A Su, Hoang A Di, and Dinh Van Xuan assisted with fieldwork. Nguyen Dinh Cong and Luu Dam Cu (Vietnam National Museum of Nature, Hanoi) facilitated specimen loan. Ross Sadlier and Cecilie Beatson provided assistance with laboratory work. This work was supported by the Ocean Park Conservation Foundation Hong Kong and ADM Capital Foundation. For all this assistance we are most grateful.

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Appendix I

Comparative material examined

- Leptolalax aereus*: Laos, Savannakhet Province, Vilabouli District (NCSM 76038–76057, 76061–76071; SAMA R64234–64242; type specimens).
- Leptolalax applebyi*: Vietnam, Quang Nam Province, Song Thanh Proposed Nature Reserve (AMS R 171703–171707; type specimens). Vietnam, Kon Tum Province, Ngoc Linh Nature Reserve (AMS R 173635, 177637, UNS 00462/AMS R 173776, AMS R 173777, AMS R 173778, UNS 00465/AMS R 173780, AMS R 176528, UNS 00464/AMS R 176529, UNS 00465/AMS R 176530, AMS R 176531–176533).
- Leptolalax bidoupensis*: Vietnam, Lam Dong Province, Bidoup-Nui Ba National Park (AMS R 173133, UNS 00101/AMS R 173135, UNS 00102/AMS R 173137, AMS R 173134, AMS R 173136, NCSM 77320, NCSM 77321, NCSM 77322; type specimens).
- Leptolalax croceus*: Vietnam, Kon Tum Province, Ngoc Linh Nature Reserve (AMS R 173738–173748, UNS 00108/ AMS R 173750, AMS R 173751, UNS 00109/AMS R 173752, UNS 00110/AMS R 173775, UNS 00111/AMS R 173779; type specimens).
- Leptolalax dringi*: Malaysia, Sarawak (AMNH A90487).
- Leptolalax eos*: Laos, Phongsaly Province (FMNH 258052–258064, 258066). Laos, Luang Namtha Province (FMNH 271281–271285).
- Leptolalax firthi*: Vietnam, Kon Tum Province, Ngoc Linh Nature Reserve (AMS R 176524, AMS R 176525, UNS 00460/ AMS R 176526, UNS 00461/AMS R 176527, AMS R 176513, UNS 00456/AMS R 176514, AMS R 176515, NCSM 78995, AMS R 176503–176507, UNS 00453/AMS R 176509, UNS 00454/AMS R 176510, UNS 00455/AMS R 176511, AMS R 176500, UNS 00452/AMS R 176501, AMS R 176502, AMS R 176508, AMS R 1765012, AMS R 176517, NCSM 78996–78997, AMS R 176518, UNS 00457/AMS R 176516, AMS R 176520, AMS R 176522, UNS 00458/AMS R 176519, AMS R 176521, UNS 00459/AMS R 176523, AMS R 173736, AMS R 173774). Vietnam, Quang Nam Province, Song Thanh Proposed Nature Reserve (AMS R 171714, AMS R 171722). Type specimens.
- Leptolalax gracilis*: Malaysia, Sarawak (AMNH A90488).
- Leptolalax liui*: China, Fukien Province, Ch'ungshan, Hsein (AMNH A30127, 30129, 30130, 30135; FMNH 22415–22418; topotypes). China, Fukien Province, Yenping (AMNH A28417).
- Leptolalax melicus*: Cambodia, Ratanakiri Province, Virachey National Park (MVZ 258074–258077, MVZ 258197– 258199; type specimens).
- Leptolalax nyx*: Vietnam, Ha Giang Province (AMNH A163798, 163799, 163802–163804, 163811–163813, 163817–163819, 163822–163824, 163828–163830; topotypes).
- Leptolalax oshanensis*: China, Sichuan Province, Hongya Xian (FMNH 232907–232921; ~50 km from type locality).
- Leptolalax sungi*: Vietnam, Lao Cai Province (AMNH 168676).
- Leptolalax tuberosus*: Vietnam, Quang Nam Province, Song Thanh Proposed Nature Reserve (AMS R 171715–171721). Vietnam, Quang Nam Province (AMNH A163665).
- Leptolalax ventripunctatus*: Laos, Phongsaly Province (FMNH 258077). Laos, Luang Namtha Province (FMNH 271317–21, 271329, 271331).