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A REVISION OF SPECIES IN THE SUBGENUS *NIDIRANA* DUBOIS, 1992, WITH SPECIAL ATTENTION TO THE IDENTITY OF SPECIMENS ALLOCATED TO *RANA ADENOPLEURA* BOULENGER, 1909, AND *RANA CHAPAENSIS* (BOURRET, 1937) (AMPHIBIA: ANURA: RANIDAE) FROM THAILAND AND LAOS

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***ABSTRACT.* –** Examination of specimens of ranid frogs in the subgenus *Nidirana* Dubois, 1992, confirms the uniqueness of these frogs based on external morphological, morphometrical and behavioral characters. The results separate the species of *Nidirana* into three species groups as 1) *Rana okinavana* group (including three species, *Rana chapaensis* (Bourret, 1937), *Rana daunchina* Chang, 1933, and *Rana okinavana* Boettger, 1895); 2) *Rana adenopleura* group (including three species, *Rana adenopleura* Boulenger, 1909, *Rana caldwelli* Schmidt, 1925, and *Rana lini* Chou, 1999); and 3) *Rana pleuraden* group (including one species, *Rana pleuraden* Boulenger, 1934). The revalidation of *Rana caldwelli* by Dubois (1992) was confirmed by morphological and morphometrical data as presented in the result. The specimens from Thailand previously listed as *Rana adenopleura* and *Rana chapaensis* are re-allocated to *Rana lini* based on external morphological characteristics. As for Laos, three specimens referred to *Rana chapaensis* were restudied and were assigned to *Rana lini*. To clarify some confusions of the original description of *Rana lini*, we provide here a re-description based on specimens from Thailand. Following our study, the recent distribution of *Rana lini* includes China (Yunnan Province), Laos (Xieang Khouang Province) and Thailand (Loei and Phetchabun Provinces). *Rana chapaensis* is known from Laos (Saravan Province) and Vietnam (Ha Tinh and Lao Cai provinces).

***KEY WORDS.* –** *Babina*, *Nidirana*, systematics, taxonomy, distribution.

INTRODUCTION

Dubois (1992) created the subgenus *Nidirana* (type species: *Rana psaltes* Kuramoto, 1985) and grouped the species included into two groups: 1) *Rana adenopleura* group (consisting of five species, *R. adenopleura* Boulenger, 1909, *R. caldwelli* Schmidt, 1925, *R. chapaensis* (Bourret, 1937), *R. daunchina* Chang, 1933, and *R. psaltes*) and 2) *Rana pleuraden* group (consisting of one species, *R. pleuraden* Boulenger, 1934). More recently Chou (1999) added a new frog from China named *R. lini*. Furthermore the species *R. psaltes* was considered a subjective junior synonym of

R. okinavana Boettger, 1895, by Matsui (2007). Based on present knowledge, the range of distribution of the species of *Nidirana* includes China, Japan, Laos, Thailand and Vietnam (Boulenger, 1904, 1909; Schmidt, 1925; Chang, 1933; Bourret, 1937, 1942; Kuramoto, 1985; Chan-ard et al., 1999; Chou, 1999; Chan-ard, 2003; Stuart, 2005; Matsui, 2007). Taxonomic status of the species of *Nidirana* needs revision as information given in original descriptions is insufficient and more specimens are now available. The identity of some recent records needs further investigation for confirmation.

Recently several species of frogs have been reported from Thailand but insufficient information for assuming their identity was provided (Chan-ard et al., 1999; Khonsue & Thirakhupt, 2001; Chuaynkern et al., 2002; Chan-ard, 2003; Chan-ard et al., 2003; Inthara et al., 2004a, b; Nabhitabhata et al., 2000; Niyomwan, 2004; Nabhitabhata & Chan-ard, 2005; Taksintum et al., 2006). In fact each species needs to be sufficiently scientifically investigated for allocation of a name. Data supporting this allocation should be given. Some of these species were re-studied and revealed to be either a new record for Thailand or a taxon new to science (Leong & Lim, 2003; Leong et al., 2003; Chuaynkern et al., 2004; Matsui et al., 2005; Stuart & Chan-ard, 2005; Bain & Stuart, 2006; Matsui & Nabhitabhata, 2006; Matsui & Panha, 2006; Ohler & Delorme, 2006; Stuart et al., 2006; Bordoloi et al., 2007).

Such a case is the occurrence of two species of frogs of the subgenus *Nidirana* in Thailand: these are *Rana adenopleura* (Chan-ard et al., 1999; Khonsue & Thirakhupt, 2001) and *R. chapaensis* (Chan-ard, 2003; Nabhitabhata & Chan-ard, 2005). *R. adenopleura* was first mentioned by Chan-ard et al. (1999) and its occurrence was confirmed by Khonsue & Thirakhupt (2001). Chan-ard et al. (1999: 17) provided an information of its concerning record as only "Chan-ard unpublished data/Chan-ard unpublizierte Daten" and its locality in Thailand was not also specified. Later, Khonsue & Thirakhupt (2001) published a checklist of amphibians of Thailand and also listed the name of *R. adenopleura*. Then Chan-ard (2003: 126-127) provided a very brief account, including a map of Thailand, and life photograph of *R. chapaensis* from Phu Luang Wildlife Sanctuary (Loei Province, northeastern Thailand; see Fig. 6). Unfortunately, all these references did not include information on voucher specimens. Additionally, these two species names (*R. adenopleura* and *R. chapaensis*) were not listed in the checklist of Nabhitabhata et al. (2000). Later however *R. chapaensis* was listed and its status considered as NT by Nabhitabhata & Chan-ard (2005).

Recently, we found valuable information at the FMNH website concerning two specimens (FMNH 262578-579) of frogs of subgenus *Nidirana* (Dubois, 1992) from Loei Province, deposited in the Field Museum of Natural History (Chicago, USA). Both specimens were collected by Tanya Chan-ard who first reported the names of *Rana adenopleura* (Chan-ard et al., 1999) and *R. chapaensis* (Chan-ard, 2003) from Thailand. Additionally, during field surveys in 2005 and 2006 we collected several specimens of this group from that and another locality: Phu Hin Rong Kla National Park (Phetchabun Province; see Fig. 6). All specimens were examined and compared with other species of *Nidirana* which were loaned from several museums (see Materials and Methods). This led to a re-evaluation of the status of the frogs collected from Thailand and Laos, but also to a revision of the species of these ranid frogs.

MATERIALS AND METHODS

The Thai specimens were caught in the field by hand, preserved in 10% buffer formalin, and later transferred to 70% ethanol. Before preservation in formalin, tissue samples were taken by cutting pieces of liver and preserving them in 95% ethanol for further molecular study. The specimens were deposited at the Thailand Natural History Museum (THNHM), Pathum Thani (Thailand) and were loaned to study at the Laboratoire des Reptiles et Amphibiens, Muséum national d'Histoire naturelle (MNHN), Paris (France). These specimens were compared in external morphological characters and morphometry with seven species of the subgenus *Nidirana* (Dubois, 1992): *Rana adenopleura*, *R. caldwelli*, *R. chapaensis*, *R. daunchina*, *R. lini*, *R. okinavana* and *R. pleuraden*.

We do not follow Frost et al. (2006) who placed the frogs of the subgenera *Babina* Van Denburgh, 1912, and *Nidirana* in the same genus because these two groups show two distinct morphotypes indicating different adaptative niches, although there is no evident apomorphy known for *Nidirana*. We therefore excluded the two species of *Babina* (*Rana holsti* Boulenger, 1892, and *R. subaspera* Barbour, 1908) from this study as their morphological and morphometric characteristics do not concern the specimens and taxa studied here. List of all material examined is provided below in the species accounts.

The description format is based on the works of Ohler (e.g., Ohler, 1996; Ohler & Dubois, 1999; Ohler et al., 2000, 2002). The specimen photographs were taken using digital camera and modified by using Adobe® Photoshop CS2. The habitat and life photographs of frog were taken in the field by using digital camera. The drawings of hand and foot were made by C. Inthara using a Leica MS5 stereomicroscope with a camera lucida attachment at the Laboratoire des Reptiles et Amphibiens (MNHN). All keratodont formulae presented by various authors were transformed to Dubois' (1995) proposal. Morphometrical analyses were made using the SPSS statistical programs for personal computers (Norusis, 1992). Non-parametric Kruskal-Wallis test and Tukey type *b* analysis (Zar, 1984) were performed to find significant statistical differences among taxa. The number of significant differences was used to obtain a phenogram using UPGMA method (Dubois, 1976).

Measurement were made with digital calipers to the nearest 0.1 mm. Abbreviations used for measurements: **SVL** = snout vent length. ***Head***: **HW** = head width; **HL** = head length

(from the back of the mandible to the tip of snout); **MN** = distance from the back of the mandible to the nostril; **MFE** = distance from the back of the mandible to the front of the eye; **MBE** = distance from the back of the mandible to the back of the eye; **IFE** = distance between the front of the eyes; **IBE** = distance between the back of the eyes; **IN** = internarial space; **EN** = Distance from the front of the eye to the nostril; **EL** = eye length; **SN** = distance from the nostril to the tip of the snout; **SL** = distance from the front of the eye to the tip of the snout; **TYD** = greatest tympanum diameter; **TYE** = distance from tympanum to the back of the eye; **IUE** = minimum distance between upper eyelids; **UEW** = maximum width of inter upper eyelid. ***Forearm***: **HAL** = hand length (from the base of the outer palmar tubercle to the tip of the toe); **FLL** = forelimb length (from the elbow to the base of the outer tubercle); **TFL** = third finger length (from the base of the first subarticular tubercle); **fd1-fd4** = width of pads of finger 1 to 4; **fw1-fw4** = width of fingers 1 to 4; ***Hindlimb***: **FL** = femur length (from vent to knee); **TL** = tibia length; **FOL** = foot length (from the base of the inner metatarsal tubercle to the tip of the toe); **FTL** = fourth toe length (from the base of the first subarticular tubercle to the tip of the toe); td1-td5 = width of pads of the toes 1 to 5; tw1 to tw5 = width of toes 1 to 5; **IMT** = length of inner metatarsal tubercle; **ITL** = inner toe length. ***Webbing***: **MTTF** = distance from the distal edge of the metatarsal tubercle to the maximum incurvation of the web between third and fourth toe; **TFTF** = distance from the maximum incurvation of the web between third and fourth toe to the tip of the fourth toe; **MTFF** = distance from the distal edge of the metatarsal tubercle to the maximum incurvation of the web between fourth and fifth toe; **FFTF** = distance from the maximum incurvation of the web between fourth and fifth toe to the tip of fourth toe; **WTF** = webbing between third and fourth toe (from the base of the first subarticular tubercle); **WFF** = webbing between fourth and fifth toe (from the base of the first subarticular tubercle); **WI** = webbing between third and fourth toe when folded along fourth toe (from the base of the first subarticular tubercle); **WII** = webbing between fourth and fifth toe when folded along fourth toe (from the base of the first subarticular tubercle).

Abbreviations of the museums and institutions in which the specimens were deposited in are as follows: AMNH = American Museum of Natural History (New York, USA); CAS = California Academy of Science (San Francisco, USA); CAS-SUA = Stanford University Collection at the California Academy of Science; FMNH = Field Museum of Natural History (Chicago, USA); MCZ = Museum of Comparative Zoology, Harvard University (Massachusetts, USA); MNHN = Muséum national d'Histoire naturelle (Paris, France); NMNS = National Museum of Natural Science (Taiwan, China); THNHM = Thailand Natural History Museum (Pathum Thani, Thailand).

RESULTS

Morphological and morphometrical comparisons

Morphological comparison of species of *Nidirana* (*Rana adenopleura*, *R. caldwelli*, *R. chapaensis*, *R. daunchina*, *R. lini*, *R. okinavana*, *R. pleuraden* and specimens from Laos and Thailand) is given in Table 1. The statistical comparisons of these taxa showed significant differences in 36 measurements (Table 4). After excluding the specimens of *R. lini* (2 adult males) and Laos specimens (2 adult males) due to the low sample-size, the phenogram representing morphological similarities between species of *Nidirana* based on the number of significantly different measurements is shown in Fig. 1. As results, the morphological and morphometrical analyses separated the species of *Nidirana* into three groups consisting of 1) *Rana okinavana* group (includes *R. chapaensis*, *R. daunchina* and *R. okinavana*); 2) *Rana adenopleura* group (includes *R. adenopleura*, *R. caldwelli*, and specimens from Laos and Thailand); and 3) *Rana pleuraden* group (includes *R. pleuraden*).

The *Rana okinavana* group is distinguished from the *Rana adenopleura* and *Rana pleuraden* groups by the following combination of characters: 1) body stocky; 2) SVL of adult males 36.8–46.8 mm, adult females 41–51.8 mm; 3) nostril directed laterally; 4) marginal grooves on fingers present or absent; 5) marginal grooves on toes present; 6) external vocal sac present or absent; 7) nuptial pad present on thumb and first finger; 8) suprabrachial gland present, large or elongate; 9) nest construction behavior present; 10) spinules on back absent or rarely few present on area above vent; 11) spinules on ventrum absent; and 12) finger tips dilated; 13) toe tips dilated.

The *Rana adenopleura* group is distinguished from the *Rana okinavana* and *Rana pleuraden* groups by the following combination of characters: 1) body slender; 2) SVL of adult males 41.1–57.9 mm, adult females 47.6–60.7 mm; 3) nostril directed laterally; 4) marginal grooves on fingers present or absent; 5) marginal grooves on toes present; 6) external vocal sac present; 7) nuptial pad present on thumb and first finger; 8) suprabrachial gland present, large; 9) nest construction behavior absent; 10) spinules on back present on back (posteriorly or whole dorsum and head); 11) spinules on ventrum present in adult male; and 12) finger tips dilated; 13) toe tips dilated.

The *Rana pleuraden* group is distinguished from *Rana okinavana* and *Rana adenopleura* groups by the following combination of characters: 1) body slender; 2) SVL of adult males 45.4–58.7 mm, adult females 47.5–60 mm; 3) nostril directed dorsally or above; 4) marginal grooves on fingers absent; 5) marginal grooves on toes absent; 6) external vocal sac present; 7) nuptial pad present on thumb and first finger; 8) suprabrachial gland present, large; 9) nest construction behavior absent; 10) spinules on back present on back (posteriorly back); 11) spinules on ventrum present in adult male; and 12) finger tips not dilated; 13) toe tips not dilated.

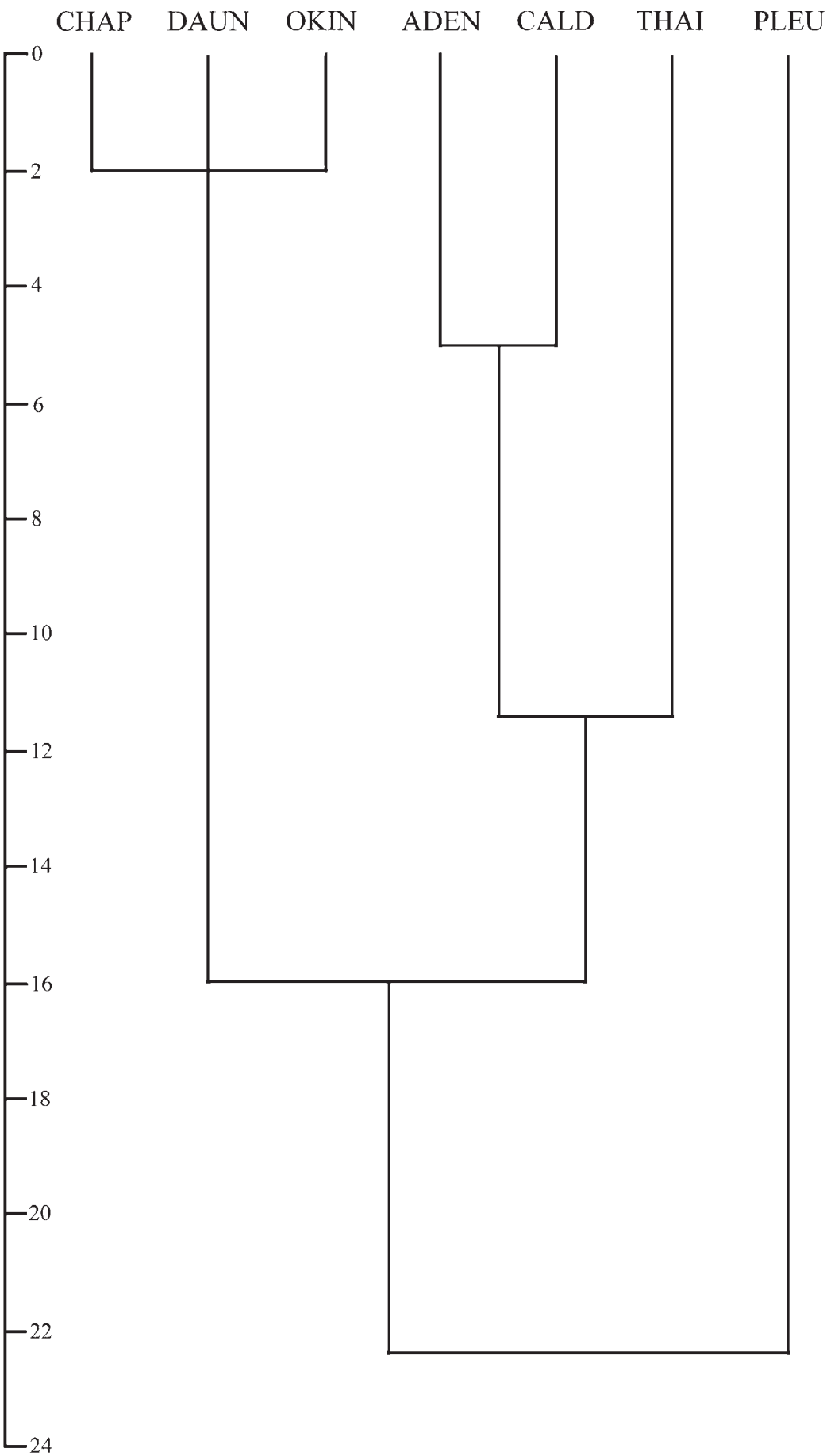

Fig. 1. Phenogram representing morphometrical similarities between species of *Nidirana* based on the number of significantly different measurements. ADEN = *Rana adenopleura*, CALD = *R. caldwelli*, CHAP = *R. chapaensis*, DAUN = *R. daunchina*, OKIN = *R. okinavana*, PLEU = *R. pleuraden* and THAI = Thai specimens.

Table 1. Selective morphological characters of *Rana adenopleura*, *R. caldwelli*, *R. chapaensis*, *R. daunchina*, *R. lini*, *R. pleuraden*, *R. okinavana*, Laos specimens and Thailand.

Characteristics	***R. adenopleura***	***R. caldwelli***	***R. chapaensis***	***R. daunchina***	***R. lini***	***R. okinavana***	***R. pleuraden***	**Laos**	**Thailand**
Body shape	Elongated	Elongated	Stocky	Stocky	Elongated	Stocky	Elongated	Elongated	Elongated
Nostril direction	Lateral	Lateral	Lateral	Lateral	Lateral	Lateral	Above	Lateral	Lateral
Finger tips	Dilated	Dilated	Dilated	Dilated	Dilated	Dilated	Not dilated	Dilated	Dilated
Marginal groove on fingers	Present/Absent	Present/Absent	Present/Absent	Absent/Rarely present	Present/Absent	Present/Absent	Absent	Present	Present/Absent
Relative length of fingers	II<I<IV<III	II<I<IV<III	II<I=IV<III	II<I<IV<III	II<I<IV<III	II<I<IV<III	II<I<III<IV	I=II<IV<III	I=II<IV<III
Toe tips	Dilated	Dilated	Dilated	Dilated	Dilated	Dilated	Not dilated	Dilated	Dilated
Marginal groove on toes	Present	Present	Present	Present	Present	Present	Absent	Present	Present
Tibio-tarsal articulation	Snout tip/ eye-snout	Snout tip	Nostril[11]	?	?	Eye center-near nostril	Eye-snout	?	Beyond snout
Relative length of toes	I<II<III=V<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<V<III<IV	I<II<III=V<IV
Mid-dorsal stripe	Present/Absent	Present/Absent	Present/Absent	Present/Absent	Present	Present	Present/Absent	Present	Present
External vocal sac	Present	Present	Present	Present	Present	Absent	Present	Present	Present
Suprabrachial gland	Large	Large	Large	Large	Large	Elongate	Large	Large	Large
Nuptial spine on finger 1	Present	Present	Present	Present	Present	Present	Present	Present	Present
Spinules on back	Entired back	Posterior back	Absent/above vent	Absent/above vent	Posterior back	Absent/above vent	Posterior back	Posterior back	Posterior back
Spinules on venter of adult male	Present	Present	Absent	Absent	Present	Absent	Present	Present, few	Present
Nest construction	Absent[2]	Absent[7]	Present[2,11]	Present[5]	Absent[2]	Present[2,4]	Absent[2]	?	?
Calling	2-4 loud “gai-gai” notes[2,9]	?	3 weak “gulo-gulo-gulo” notes[2,10]	2-3 weak “dune-dune” musical notes[2]	5-7 loud “goo-goo-…” notes[2]	17-25 loud, fast-repeated, “gulo” pulses[2]	4-7 loud “guo-guo” notes[2]	?	?
Larval keratodont	1:1+1/1+1:2[3]	1:0+0/1+1:2[7]	1:1+2/1+1:2[12]	1:1+1/2+2:1[5]	1:1+1/1+1:2[2]	1:1+1/1+1:2[4] 1:1+1/1+1:2[6]	1+1:1[13] 1+2:2[13] 2+1:1[13] 2+2:2[13]	?	?

Note: 1=Boulenger (1920); 2=Chou (1999); 3=Chou & Lin (1997); 4=Kuramoto (1985); 5=Liu (1950); 6=Maeda & Matsui (1990); 7=Pope (1931); 8=Schmidt (1927); 9=Matsui & Utsunomiya (1983); 10=Bourret (1942); 11=Ohler (unpublished observation); 12=Grosjean (2004); Liu & Hu (1961).

Table 2. Significant differences ($p < 0.05$) of measurements among adult males of seven taxa. ADEN=*Rana adenopleura*, CALD=*R. caldwelli*, CHAP=*R. chapaensis*, DAUN=*R. daunchina*, OKIN=*R. okinavana*, PLEU=*R. pleuraden* and THAI=Thai specimens.

	ADEN	CALD	CHAP	DAUN	PLEU	OKIN	THAI
ADEN		5	6	21	27	7	8
CALD			30	20	24	6	15
CHAP				16	35	2	20
DAUN					27	2	21
PLEU						16	26
OKIN							10
THAI							

Morphological and morphometrical comparisons of the specimens from Thailand and Laos with the species of *Nidirana* was respectively mentioned in the "Comparison of the specimens from Thailand" and the "Allocation of the specimens from Laos".

COMPARISON OF THE SPECIMENS FROM THAILAND

Inter population comparison

Inter-population variation in size and proportions of the Thai specimens is presented in Table 3. The statistical comparison of adult specimens from Loei and Phetchabun provinces revealed that those frogs do not have highly significant difference. There were only slight morphometrical differences on relative lengths of HW, IBE, IN, FL, TW, ITL, WTF, WFF, WI, and WII, which show slight significant differences (Mann-Whitney *U* test, $0.01 < p \leq 0.05$). For the comparison of adult females, we excluded from this test according to the low sample-size available (only an adult female was collected from Loei Province). The adult males from Loei (SVL 54.7 ± 1.8, 53.1–56.4 mm) and Phetchabun (SVL 56.3 ± 1.2, 54.2–57.9 mm) provinces are smaller size than adult female (SVL 60.7 mm).

When considering the frogs from those two localities together, the outer metatarsal tubercles are usually present but can be absent. Pineal ocellus is usually present but can be absent as well. The marginal grooves on first and second fingers maybe present or absent but are always present in third and fourth fingers. The mid-dorsal stripe is present in all specimens but maybe interrupted. Despite the variation described, we consider those frogs as belonging to the same species.

Comparison with the "*Rana adenopleura* Group"

The specimens from Thailand differ from *Rana adenopleura* by having dense white spinules only on posterior back whereas *R. adenopleura* possesses spinules on the whole dorsum. This character is observed in both sexes but is more distinct in adult males. In the Thai specimens, nuptial spines reach only the position of subarticular tubercle on first finger but in *R. adenopleura* nuptial spines go beyond to the distal articulation. When hind legs were folded along the body, the tibiotarsal articulation of Thai specimens goes beyond snout, but Boulenger (1909, 1920) described it in *R. adenopleura* as reaching the tip of the snout or between the eye and the tip of the snout. Adult male specimens from Thailand show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) from *R. adenopleura* in eight morphometrical characters: SVL, RHW, REN, RFL, RTL, RTFTF, RFFTF, and RWTF. Thus the morphometric analysis support that the size of Thai specimens is larger than *R. adenopleura*. Moreover, it has narrower head and longer loreal region than *R. adenopleura*; its thigh and tibia are longer than *R. adenopleura*; its webbing between third and fourth toes, and between fourth and fifth toes are smaller than *R. adenopleura*. Its webbing between third and fourth toes when folded along fourth toe is also smaller than *R. adenopleura*.

The taxonomic status of *Rana caldwelli* is problematic. This species is similar to *R. adenopleura*. Several authors placed *R. caldwelli* in the synonymy of *R. adenopleura* (Pope, 1931; Liu, 1950; Kuramoto, 1985; Chou, 1999). However, Dubois (1992) proposed to use the name of *R. caldwelli* for Fujian population and restricted the name of *R. adenopleura* for Taiwan population. He based his decision on published evidences which said that the Fujian population can be distinguished in several characters. There are: (1) Fujian population has longer tibia than Taiwan population (Boulenger, 1920; Schmidt, 1927; Kuramoto, 1985), (2) the presence of tarsal fold (Boulenger, 1920; Schmidt, 1927), and (3) the presence of single row of keratodonts on upper part in tadpole (Pope, 1931).

For the first character of Dubois (1992), our data show that the Fujian population does not significantly differ from Taiwan population. Moreover, the Fujian frogs have slightly shorter tibia than Taiwan frogs. According to our observation, the second character (tarsal fold) is absent in Fujian frogs which different to description of Boulenger (1920) and Schmidt (1927). Karl P. Schmidt who described this frog in 1925 but did not mention the tarsal fold in his

Table 3. Comparison of adult male specimens of *Nidirana* from Loei and Phetchabun Provinces by Mann-Whitney *U* test. n, sample size; p, probability; *U*, Mann-Whitney *U*; ns, not significant. Significance level $p > 0.05$ ns; $0.01 < p \leq 0.05$ *; $0.001 < p \leq 0.01$ **; $p \leq 0.001$ ***.

	Loei n = 4	**Phitsanulok n = 6**	**Mann-Whitney U test**		**Loei n = 4**	**Phitsanulok n = 6**	**Mann-Whitney U test**
SVL	54.7 ± 1.8 (53.1–56.4)	56.3 ± 1.2 (54.2–57.9)	U = 4 p = 0.088 ns	RFLL	205 ± 10.5 (190–215)	216 ± 8.6 (201–220)	U = 6 p = 0.201 ns
RHW	343 ± 7 (333–349)	315 ± 1.8 (312–317)	U = 0 p = 0.01*	RTFL	155 ± 13.1 (131–160)	164 ± 5.7 (153–170)	U = 4 p = 0.088 ns
RHL	400 ± 6 (389–401)	392 ± 10.7 (386–414)	U = 9 p = 0.522 ns	RFL	502 ± 16.3 (486–525)	529 ± 14.8 (521–556)	U = 1 P = 0.019*
RMN	323 ± 8.4 (312–332)	324 ± 7.2 (318–334)	U = 10 p = 0.67 ns	RTL	589 ± 23.8 (546–596)	594 ± 10.7 (576–608)	U = 9 p = 0.522 ns
RMFE	247 ± 4.2 (244–253)	240 ± 11 (232–263)	U = 4 p = 0.088 ns	RFOL	622 ± 32.8 (568–646)	601 ± 8.2 (595–617)	U = 6 p = 0.201 ns
RMBE	149 ± 3.8 (145–154)	151 ± 6.7 (142–160)	U = 9 p = 0.522 ns	RFTL	384 ± 22.1 (436–397)	376 ± 4.7 (367–381)	U = 6 p = 0.201 ns
RIFE	171 ± 8.2 (158–175)	162 ± 4.8 (153–166)	U = 5 p = 0.136 ns	RIMT	51 ± 4.4 (46–55)	48 ± 2.3 (46–51)	U = 7 p = 0.286 ns
RIBE	248 ± 10.4 (236–259)	221 ± 5.3 (213–227)	U = 0 p = 0.011*	RITL	136 ± 11.3 (116–141)	147 ± 4.6 (140–154)	U = 1 p = 0.019*
RIN	114 ± 3.5 (109–116)	98 ± 5.1 (93–106)	U = 0 p = 0.011*	RTW	132 ± 2.7 (129–136)	145 ± 7.4 (136–152)	U = 0 p = 0.011*
REN	91 ± 7.5 (83–101)	92 ± 2.7 (89–97)	U = 11 p = 0.831 ns	RTFOL	872 ± 39.5 (799–883)	852 ± 23.1 (812–869)	U = 8 p = 0.394 ns
REL	112 ± 4.3 (106–116)	112 ± 1.6 (109–113)	U = 10 p = 0.67 ns	RMTTF	249 ± 19.5 (218–265)	261 ± 7.5 (250–269)	U = 6 p = 0.201 ns
RNS	74 ± 9.6 (68–89)	83 ± 7.3 (69–92)	U = 7 p = 0.286 ns	RMTFF	276 ± 14.1 (260–291)	296 ± 10.1 (279–307)	U = 3 p = 0.055 ns
RSL	173 ± 8 (158–175)	173 ± 5.7 (162–178)	U = 11 p = 0.831 ns	RTFTF	317 ± 31.6 (260–328)	300 ± 5.7 (292–307)	U = 6 p = 0.201 ns
RTYD	93 ± 5.8 (83–95)	94 ± 3.9 (93–101)	U = 7 p = 0.286 ns	RFFTF	322 ± 45.4 (243–346)	284 ± 6.7 (271–290)	U = 6 p = 0.201 ns
RTYE	33 ± 3.3 (30–38)	34 ± 3.1 (30–38)	U = 9 p = 0.522 ns	RWTF	77 ± 3.2 (74–80)	93 ± 3.3 (88–96)	U = 0 p = 0.011*
RIUE	91 ± 9.4 (83–102)	87 ± 3 (82–91)	U = 10 p = 0.67 ns	RWFF	88 ± 11.6 (78–104)	116 ± 6.6 (106–122)	U = 0 p = 0.011*
RUEW	68 ± 3.1 (65–72)	72 ± 2.9 (67–75)	U = 5 p = 0.136 ns	RW1	63 ± 6.5 (55–68)	73 ± 3.9 (70–80)	U = 0 p = 0.011*
RHAL	257 ± 15.4 (230–263)	265 ± 7.7 (251–274)	U = 3 p = 0.055 ns	RW2	75 ± 9 (68–88)	97 ± 3.3 (91–100)	U = 0 p = 0.011*

diagnosis (Schmidt, 1925: 2) but this character was mentioned as "a tarsal fold present" in his subsequent work (Schmidt, 1927: 571). Boulenger (1920: 140) noted this character as "no tarsal fold" in the type specimens of *Rana adenopleura* from Taiwan which corresponds to our observation of several specimens from Taiwan.

As a result, we recognize the name *Rana caldwelli* as valid species even though the first and second characters of Dubois (1992) did not agree with our examination. An important reason for this decision is that we did not examine the type specimens of *R. caldwelli*. Moreover, the adult males of Fujian specimens differ statistically highly from the Taiwan frogs in five morphometrical characters (Mann-Whitney *U* test, $p \leq 0.001$; i.e. RMN, REN, RFLL, RTW, and Rtd5), supporting statistically that *R. adenopleura* has longer loreal region, longer forelimb, narrower shank, and wider disc of the fifth toe than *R. caldwelli*. Schmidt (1925, 1927) distinguished *R. caldwelli* (based upon two specimens from Fujian) from *R. adenopleura* by their more projecting snouts, rougher skin and posteriorly broken up dorsolateral glandular folds. Our examination on Fujian and Taiwan frogs (not type specimens) correspond to his observations. However, we found that the adult male from Taiwan has spinules on the dorsum scattered from tip of snout to vent but the Fujian male has only the posterior half of dorsum covered with spinules (Table 1).

The Thai specimens differ from *Rana caldwelli* by nuptial spines on first finger reaching above the position of subarticular tubercle whereas in *R. caldwelli* they cover beyond to position of distal articulation. Thai adult male

Table 4. Morphometric data for adult males of *Rana adenopleura*, *R. caldwelli*, *R. chapaensis*, *R. daunchina*, *R. lini*, *R. pleuraden*, *R. okinavana*, specimens from Laos and Thailand.

	R. adenopleura	***R. caldwelli***	***R. chapaensis***	***R. daunchina***	***R. lini***	***R. okinavana***	***R. pleuraden***	**Laos**	**Thailand**	**Kruskal-Wallis**
SVL	48.5 ± 2.7 (44.6–53.9)	49 ± 3.2 (43.1–56.1)	40.9 ± 1.9 (36.8–44.2)	44 ± 1.5 (40.6–46.8)	45.4 ± 1.9 (44.1–46.7)	41.7 ± 1.4 (40–42.8)	50.5 ± 3.1 (45.4–58.7)	54.3	55.7 ± 1.6 (53.1–57.9)	97.2***
RHW	344 ± 12 (318–368)	336 ± 11 (319–365)	364 ± 14 (335–392)	369 ± 16 (346–394)	341 ± 6 (337–345)	352 ± 12 (343–372)	330 ± 14 (289–349)	308	317 ± 15 (312–349)	73.2***
RHL	384 ± 10 (361–400)	378 ± 10 (358–394)	395 ± 13 (364–426)	381 ± 9 (365–398)	382 (382–382)	398 ± 17 (365–400)	371 ± 12 (335–392)	380	398 ± 9 (386–414)	55.1***
RMN	324 ± 10 (292–337)	308 ± 12 (289–348)	314 ± 12 (296–339)	313 ± 10 (289–324)	322 ± 11 (313–330)	326 ± 14 (301–331)	314 ± 14 (271–331)	309	323 ± 7 (312–334)	26.3***
RMFE	250 ± 9 (231–261)	238 ± 11 (216–256)	249 ± 10 (232–270)	242 ± 11 (289–324)	248 ± 5 (245–252)	261 ± 7 (251–269)	248 ± 14 (215–269)	226	243 ± 9 (232–263)	21.9***
RMBE	153 ± 10 (132–167)	143 ± 8 (130–158)	150 ± 11 (128–162)	242 ± 11 (226–269)	149 ± 5 (146–152)	154 ± 13 (137–167)	161 ± 14 (123–175)	136	150 ± 6 (142–160)	27***
RIFE	164 ± 12 (146–189)	164 ± 12 (153–210)	190 ± 9 (176–211)	134 ± 10 (122–157)	167 ± 4 (164–170)	183 ± 5 (176–189)	153 ± 6 (143–170)	160	163 ± 7 (153–175)	78***
RIBE	230 ± 11 (213–255)	237 ± 17 (169–261)	262 ± 7 (254–283)	246 ± 12 (227–270)	242 ± 16 (231–253)	267 ± 18 (239–281)	222 ± 12 (200–241)	219	225 ± 16 (213–259)	72.8***
RFLL	223 ± 9 (203–235)	205 ± 12 (192–236)	231 ± 9 (212–250)	218 ± 11 (201–245)	214 ± 3 (212–216)	225 ± 9 (210–232)	196 ± 9 (179–212)	204	211 ± 10 (190–220)	72.4***
RHAL	245 ± 13 (221–282)	246 ± 13 (234–275)	261 ± 16 (231–289)	233 ± 15 (212–261)	243 ± 6 (239–247)	242 ± 7 (234–248)	240 ± 16 (207–276)	248	263 ± 13 (230–274)	30.3***
RTFL	145 ± 8 (130–163)	146 ± 9 (137–174)	158 ± 9 (138–170)	136 ± 9 (114–149)	147 ± 2 (146–148)	140 ± 9 (126–146)	142 ± 12 (110–158)	134	160 ± 11 (131–170)	45.9***
RTL	543 ± 21 (503–573)	525 ± 23 (487–566)	547 ± 18 (511–580)	524 ± 19 (478–544)	572 ± 25 (555–590)	505 ± 6 (502–517)	488 ± 25 (440–531)	562	594 ± 17 (546–608)	77.2***
RFOL	586 ± 30 (507–626)	560 ± 28 (529–618)	576 ± 27 (517–627)	542 ± 24 (459–560)	612 ± 4 (610–615)	559 ± 9 (549–570)	559 ± 37 (496–647)	587	606 ± 21 (568–646)	38.6***
RFTL	348 ± 21 (294–379)	336 ± 22 (305–390)	330 ± 19 (274–352)	313 ± 14 (265–322)	356 ± 14 (346–366)	319 ± 22 (294–346)	332 ± 25 (294–394)	361	377 ± 13 (346–397)	52***
RIN	108 ± 6 (96–118)	103 ± 11 (94–136)	136 ± 8 (122–149)	130 ± 8 (117–143)	116 ± 12 (115–117)	126 ± 2 (125–130)	87 ± 8 (72–106)	99	105 ± 8 (93–116)	102.4***
REN	83 ± 5 (73–89)	73 ± 6 (63–87)	86 ± 5 (78–96)	78 ± 4 (67–84)	91 ± 1 (91–92)	85 ± 5 (81–90)	78 ± 7 (61–90)	89	92 ± 5 (83–101)	71.5***
REL	113 ± 8 (100–131)	104 ± 9 (74–119)	117 ± 6 (110–131)	116 ± 9 (89–123)	112 ± 6 (108–117)	129 ± 7 (120–136)	102 ± 10 (84–124)	106	112 ± 3 (106–116)	44.6***
RTYD	85 ± 7 (73–100)	78 ± 7 (70–98)	88 ± 6 (78–101)	82 ± 7 (74–98)	77 ± 2 (76–78)	84 ± 4 (81–88)	76 ± 6 (66–91)	80	94 ± 5 (83–101)	49.8***
RTYE	32 ± 4 (22–42)	31 ± 5 (22–457)	29 ± 5 (20–43)	43 ± 4 (39–51)	40 ± 5 (37–44)	31 ± 2 (30–36)	40 ± 5 (28–46)	39	34 ± 3 (30–38)	67.5***

Table 4. Cont'd.

	R. adenopleura	*R. caldwelli*	*R. chapaensis*	*R. daunchina*	*R. lini*	*R. okinavana*	*R. pleuraden*	Laos	Thailand	Kruskal-Wallis
RIUE	82 ± 6 (69–93)	84 ± 8 (63–96)	106 ± 8 (90–121)	97 ± 12 (84–133)	89 ± 5 (86–93)	90 ± 7 (88–103)	67 ± 5 (57–78)	83	87 ± 6 (82–102)	98.7***
RUEW	65 ± 8 (55–81)	73 ± 6 (58–83)	80 ± 5 (74–89)	69 ± 7 (53–80)	56 ± 5 (53–59)	80 ± 4 (74–83)	67 ± 6 (62–84)	62	70 ± 3 (65–75)	55***
RWTF	107 ± 17 (59–135)	108 ± 12 (89–127)	49 ± 12 (27–87)	46 ± 7 (33–58)	64 ± 21 (50–79)	67 ± 5 (62–75)	72 ± 12 (48–91)	83	89 ± 8 (74–96)	98.7***
RWFF	116 ± 18 (57–134)	115 ± 13 (97–145)	62 ± 12 (41–88)	50 ± 9 (33–68)	76 ± 23 (59–92)	81 ± 17 (76–112)	80 ± 14 (56–119)	91	107 ± 15 (78–122)	96***
RW1	97 ± 18 (34–112)	96 ± 12 (72–119)	31 ± 12 (13–67)	23 ± 9 (11–42)	49 ± 29 (28–69)	56 ± 5 (49–61)	52 ± 11 (36–81)	69	70 ± 8 (55–80)	105***
RW2	86 ± 19 (36–113)	86 ± 13 (53–111)	46 ± 9 (29–61)	13 ± 9 (0–28)	60 ± 27 (40–79)	63 ± 12 (56–85)	43 ± 11 (24–68)	64	93 ± 11 (68–100)	99.9***
RIMT	47 ± 6 (43–63)	52 ± 4 (46–60)	56 ± 6 (47–72)	62 ± 14 (51–105)	47 ± 5 (43–50)	61.61 ± 2.68 (60–66)	49 ± 5 (40–56)	39	49 ± 3 (46–55)	63.3***
RITL	143 ± 8 (125–154)	133 ± 8 (115–149)	137 ± 8 (128–156)	125 ± 27 (111–209)	137 ± 8 (131–142)	131 ± 8 (123–138)	124 ± 8 (111–140)	136	143 ± 10 (116–154)	46.6***
RMTTF	294 ± 34 (192–327)	266 ± 27 (229–325)	222 ± 45 (21–254)	196 ± 12 (163–204)	239 ± 21 (224–254)	220 ± 14 (210–241)	225 ± 22 (202–275)	279	256 ± 15 (218–269)	86.4***
RMTFF	320 ± 34 (224–351)	283 ± 24 (261–352)	254 ± 53 (22–306)	213 ± 16 (180–229)	282 ± 21 (267–296)	254 ± 13 (243–275)	247 ± 25 (210–304)	294	289 ± 15 (260–307)	79***
RTFTF	239 ± 21 (203–282)	223 ± 19 (194–277)	303 ± 64 (24–326)	266 ± 12 (246–289)	297 ± 15 (286–307)	243 ± 20 (230–276)	259 ± 28 (222–321)	290	303 ± 19 (260–328)	72.1***
RFFTF	243 ± 17 (198–265)	224 ± 20 (198–273)	293 ± 63 (22–340)	272 ± 16 (252–317)	276 ± 23 (260–292)	234 ± 10 (224–245)	276 ± 25 (228–344)	262	284 ± 30 (243–346)	69.1***
RFL	476 ± 23 (429–517)	466 ± 27 (430–531)	512 ± 110 (18–558)	505 ± 20 (468–548)	569 ± 10 (563–576)	467 ± 14 (455–486)	457 ± 24 (405–494)	475	527 ± 22 (486–556)	58.1***
RSL	160 ± 7 (142–172)	155 ± 9 (140–186)	181 ± 37 (14–203)	159 ± 11 (136–178)	163 ± 10 (156–170)	174 ± 7 (163–179)	157 ± 9 (135–172)	177	173 ± 6 (158–178)	54.2***
RNS	74 ± 8 (54–93)	77 ± 6 (66–93)	86 ± 18 (11–106)	89 ± 21 (68–167)	80 ± 3 (78–82)	83 ± 6 (77–91)	76 ± 8 (56–93)	90	82 ± 8 (68–92)	47.4***
RTW	120 ± 10 (105–143)	138 ± 9 (117–152)	152 ± 32 (14–179)	145 ± 11 (120–167)	136 ± 15 (125–147)	147 ± 14 (128–162)	139 ± 12 (123–163)	128	138 ± 9 (129–152)	44***
RTFOL	802 ± 34 (706–844)	770 ± 39 (697–831)	803 ± 171 (20–862)	753 ± 28 (700–794)	838 ± 13 (829–847)	741 ± 28 (733–793)	745 ± 43 (671–844)	823	860 ± 29 (799–883)	44.6***

specimens show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) from *R. caldwelli* in fifteen morphometrical characteristics: SVL, RHL, RMN, REN, RSL, RTYD, RFL, RTL, RFTL, RTFOL, RTFTF, RFFTF, RWTF, Rfd1 and Rtd5. Thus the morphometric analysis support that the size of Thai specimens is larger than *R. caldwelli*. Moreover, it has longer head, snout and loreal region. Its tympanum is larger than *R. caldwelli*. Its thigh, shank, fourth toe and distance from base of tarsus to tip of fourth toe are longer than *R. caldwelli*. Its webbing between third and fourth toes, and between fourth and fifth toes are smaller than *R. caldwelli*. Webbing between third and fourth toes when folded along fourth toe is also smaller than *R. caldwelli*.

Comparison with the "*Rana okinavana* Group"

The specimens from Thailand differ from *Rana chapaensis* by having more densely white spinules on posterior back whereas no or few white spinules can be found above vent in *R. chapaensis*. In Thai specimens, nuptial pads are present on prepollex and first finger forming one single pad whereas in *R. chapaensis* is present as two separated pads. In adult males of Thai specimens, chin, throat and belly show fine spinules but this character is absent in adult males of *R. chapaensis*. Adult males of Thai specimens and *R. chapaensis* show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) in twenty morphometrical characters: SVL, RHW, RIFE, RIBE, RIN, RIUE, RUEW, RFLL, RFTL, RIMT, RMTTF, RMTFF, RWTF, RWFF, Rfd1, Rfd2, Rfd3, Rfd4, Rfw1 and Rtd5. Thus the morphometric analysis support that the specimens from Thailand have larger size than *R. chapaensis*. It has narrower head, distances between front and back of eyes, internarial space, minimum and maximum distances between upper eyelids than *R. chapaensis*. Its forelimb is shorter than *R. chapaensis*. It has longer fourth toe length but shorter inner metatarsal tubercle than *R. chapaensis*. For webbing, it has more webbing between third and fourth toes and between fourth and fifth toes than *R. chapaensis*.

The specimens from Thailand differ from *Rana daunchina* by having spinules on posterior half of back whereas these spinules are absent or few above the vent in *R. daunchina*. These spinules are present in both sexes but more dense in adult male. In Thai specimens, marginal grooves on fingers 1 and 2 are present or absent, on finger 3 and 4 are present but in *R. daunchina* these grooves are always absent. Concerning morphometrical analysis between adult males, the Thai specimens and *R. daunchina* show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) in twenty-one morphometrical characters: SVL, RHW, RHL, RIBE, RIN, REN, RTYD, RTYE, RHAL, RTFL, RTL, RFOL, RFTL, RIMT, RITL, RTFOL, RMTTF, RMTFF, RTFTF, RWTF, RWFF and Rfw1. Thus, the morphometric analysis support the specimens from Thailand having larger size than *R. daunchina*. It has narrower distance between back of eyes and internarial space than *R. daunchina*. Its head and loreal region are longer than *R. daunchina*. Its tympanum is larger and closer to eye than *R. daunchina*. Its hand and third finger are longer than *R. daunchina*. Its tibia, foot, first and fourth toes, foot and tarsus are longer than *R. daunchina*. Its inner metatarsal tubercle is shorter than *R. daunchina*. It has more webbing than *R. daunchina*.

The specimens from Thailand differ from *Rana okinavana* by having suprabrachial gland less elongated. Spinules on chin, throat, and belly are present in adult males of Thai specimens but absent in adult males of *R. okinavana*. Spinules are present on posterior half of back of Thai specimens but absent or rare and restricted to region above the vent in *R. okinavana*. In Thai specimens, nuptial pad is observed on prepollex and first finger forming a single pad whereas absent on prepollex but poorly developed as small pad on median surface of first finger in *R. okinavana*. Kuramoto (1985: 151) reported the absence of nuptial pad (as "no nuptial pad") in *R. okinavana* (as *R. psaltes*), but our observation is in agreement with Maeda & Matsui (1990, as *R. psaltes*) and Matsui (2007). When hind legs were folded along body, tibiotarsal articulation in Thai specimens goes beyond snout, but Matsui (2007) described it in *R. okinavana* as reaching between anterior border of eye and nostril. In morphometrical analysis between adult males, Thai specimens and *R. okinavana* show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) in ten morphometrical characters: SVL, RHW, RIBE, RIN, RTL, RFTL, RIMT, RTFOL, RFFTF and Rfw1. Thus the morphometric analysis support the specimens from Thailand having larger size than *R. okinavana*. Its head, distance between back of eyes and internarial space are narrower than *R. okinavana*. Its tibia, fourth toe, and tarsus and foot are longer than *R. okinavana* but its inner metatarsal tubercle is shorter than *R. okinavana*. Its webbing between fourth and fifth toes is lesser than *R. okinavana*.

Comparison with the "*Rana pleuraden* Group"

The specimens from Thailand differ from *Rana pleuraden* by having fingers and toe tips dilated which are not dilated in *R. pleuraden*. In Thai specimens marginal grooves on first and second fingers are present or absent, but always present on third and fourth fingers; in *R. pleuraden* this character is always absent. Marginal grooves on all toes of Thai specimens are also present but those are absent in *R. pleuraden*. Nostril is directed posterolaterally in Thai whereas directed dorsally in *R. pleuraden*. In morphometrical analysis between adult males, Thai specimens and *R. pleuraden* show highly significant differences (Mann-Whitney *U* test, $p \leq 0.001$) in twenty-six morphometrical characters: SVL, RHL, RIN, REN, RSL, RTYD, RIUE, RTFL, RFL, RTL, RFOL, RFTL, RITL, RTFOL, RMTFF, RTFTF, RWFF, Rfd2, Rfd3, Rfd4, Rtd1, Rtd2, Rtd3, Rtd4, Rtd5 and Rtw5. Thus the morphometric analysis support the specimens from Thailand having larger size than *R. pleuraden*. Its head, snout, and loreal region are longer than *R. pleuraden*. Its tympanum is larger than *R. pleuraden*. Its internarial and distance between upper eyelid are wider than *R. pleuraden*. Its third finger is longer than *R. pleuraden*. Its thigh, tibia, foot, first and fourth toes, and tarsus and foot are longer than *R. pleuraden*. Its

webbing between third and fourth, and between fourth and fifth toes are larger than *R. pleuraden*. Its second, third and fourth finger discs are wider than *R. pleuraden*. Its second, third, fourth and fifth toe discs are wider than *R. pleuraden*. Its width of fifth toe is larger than *R. pleuraden*.

Comparison with *Rana lini* and allocation of the specimens from Thailand

The low sample-size of adult males of *Rana lini* (two adult males) does not allow us to compare statistically with other species of *Nidirana*. Hence, we excluded these two specimens from the analysis. However, based on morphological comparison, this species should be placed in the *R. adenopleura* group by the following combination of characters: body slender, spinules on posterior half of back only, nest construction behavior absent.

As presented above, it is evident that the specimens from Thailand are quite different from most species from those *Rana okinavana* and *Rana pleuraden* groups but should be placed in the *Rana adenopleura* group (see Table 1 and Fig. 1). It is very difficult to differentiate the specimens from Thailand from *Rana lini* based on external morphological characters presented above. The statistical comparisons of two taxa are not considered here due to the low sample-sized should be lead us misinterpretation. However, the body size of adult male specimens from Thailand (53.1–57.9 mm, n = 10) is larger than *R. lini* (44.1–46.7 mm, n = 2). If the measurements of body size given by Chou (1999) are included, the size of specimens from Thailand falls into the range (44.2–61.2 mm, n = 9) of Chou's measurement. Therefore, we re-allocated here those specimens from Thailand to *R. lini*.

Allocation of the specimens from Laos

Stuart (2005) recorded *Rana chapaensis* for the first time from Laos from the provinces of Xieng Khouang and Saravan. The specimens from Saravan Province (FMNH 262576–577) were re-examined and we agree with Stuart (2005) for assigning those two specimens to *R. chapaensis*. In addition, Stuart (2005) did not refer to another specimen that was collected at the same time and from the same locality. This specimen, THNHM 02736 (an adult male with SVL 42.9 mm), was included in this study and was assigned to *R. chapaensis* as well. However for the remaining two specimens from Xieng Khouang Province (FMNH 256531–532) we do not agree with species allocation. We assign those specimens to *R. lini* based on morphological characters as presented in Table 1. On the other hand, its differs from *R. chapaensis* by having body slender (body stocky in *R. chapaensis*), more densely white spinules on posterior back (no or few white spinules on the position above vent in *R. chapaensis*), nuptial pad present on prepollex and first finger forming one single pad (separated to two pads in *R. chapaensis*), fine spinules on chin, throat and belly (absent in *R. chapaensis*). Thus for now *R. chapaensis* is mentioned from southern Laos only (Saravan Province) whereas *R. lini* is reported from northern Laos (Xieng Khouang Province). The distribution map of *R. lini* and *R. chapaensis* is shown in Fig. 6.

KEY TO SPECIES AND SPECIES ACCOUNTS

Key to species

For identification, the seven species of *Nidirana* may be distinguished as follows:

1. Marginal grooves on toe discs present, nostril directed laterally 2
– Marginal grooves on toe discs absent, nostril directed dorsally ..... *Rana pleuraden* (*Rana pleuraden* group)
2. Spinules on ventrum present (in male), spinules on back present at least posterior half (in male & female) .... 3 (*Rana adenopleura* group)
– Spinules on ventrum absent (in male & female), spinules on back absent or few on position above vent (in male & female) .... 5 (*Rana okinavana* group)
3. Spinules scattered on the whole dorsal part of head and body ..... *Rana adenopleura*
– Spinules scattered on posterior half on back 4
4. Nuptial spines on first finger reaching distal articulation .... *Rana caldwelli*
– Nuptial spines on first finger reaching above subarticular tubercle ..... *Rana lini*
5. Marginal grooves on finger and toe discs present 6
– Marginal grooves on finger discs absent, present on toe discs ..... *Rana daunchina*
6. Nuptial spines present on prepollex and first finger .... *Rana chapaensis*
– Nuptial spines absent on prepollex, present but poorly developed on first finger ..... *Rana okinavana*

SPECIES ACCOUNTS

For all seven species information concerning synonymy, specimens studied, taxonomic notes, diagnostic characters and recent distribution is provided.

Rana okinavana group

Rana chapaensis (Bourret, 1937)

Hylarana chapaensis Bourret, 1937: 34. [Syntypes: MNHN 1938.58–65 and 1948.144–147 (12 specimens) (formerly LSNUH). MNHN 1938.61 (formerly LSNUH Z 270), designated lectotype by Dubois (1992). Type-locality: "Chapa" (=Sa Pa), Lao Cai Province, Vietnam.]

Material examined. – Laos: Saravan Province, Samoy District, Xe Sap National Biodiversity Conservation Area (FMNH 262576–577, THNHM 02736). Vietnam: Ha Tinh Province, Huong Son (AMNH A 161182–183, AMNH A 161186–187); Lao Cai Province, Sa Pa (MNHN 1999.5865–885).

Taxonomic notes. – *Rana chapaensis* was described by Bourret (1937; as *Hylarana chapaensis*) based on thirteen specimens collected from Chapa (Vietnam). Chou (1999: 391, table 1) examined vocal sacs in this species as "indistinct".

Our examination showed distinct external vocal sacs visible as wrinkled skin on throat at the corner of lower jaw. The nuptial pads of this species form two largely separated pads on prepollex and median surface of first finger.

***Diagnostic characters.* –** *Rana chapaensis* is characterized by the following combination of characters: (1) body stocky; (2) SVL of adult males 40.8 ± 1.9 (36.8–44.2 mm), adult females 45.8 ± 3.3 (41.0–51.8 mm); (3) nostril directed laterally; (4) marginal grooves on fingers present or absent; (5) marginal grooves on toes present; (6) mid-dorsal stripe present or absent; (7) external vocal sac present; (8) nuptial pad present, separated into two pads (on prepollex and median surface of first finger); (9) suprabrachial gland present and large; (10) nest construction behavior present; (11) spinules on back absent or few above vent; (12) spinules on ventrum absent; (13) tibio-tarsal articulation to level of nostril; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I=IV<III; (17) relative length of toes I<II<V<III<IV; (18) pigmented eggs; (19) larval keratodont formula 1:1+2/1+1:2; (20) Calling: 3 weak "gulo-gulo-gulo" notes, like playing a rubber band on a little box.

***Distribution.* –** Laos (Saravane Province); Vietnam (Ha Tinh and Lao Cai provinces).

Rana daunchina Chang, 1933

Rana musica Chang and Hsü, 1932: 137 (nec *Rana musica* Linnaeus, 1758) [Types formerly Biol. Lab. Sci. Soc. China 6085, presumed lost in WW II. Type-locality: a pond of Hountsingping (= Hungchun-ping), Mount Omei, Omeihsien, 1300 meters altitude, Sichuan, China.]

Rana daunchina Chang, 1933: 209. Replacement name for *Rana musica* Chang and Hsü, 1932.

***Material examined.* –** China: Sichuan Province, Hongya Xian (FMNH 232892–893), Mt. Omei (AMNH A 49752, 49794, MCZ A-25747), western Sichuan (FMNH 15177), no exactly locality (FMNH 18969–970, 18976, 18978–979, 18981, 18984–986, 18989–990, 19145–148, 19166).

***Taxonomic notes.* –** Chang & Hsü (1932) described *Rana musica* from Sichuan (China) and later Chang (1933) replaced the name for *R. musica* by *R. daunchina*. Chou (1999: 391, table 1) examined vocal sacs in this species as "indistinct". Our examination showed distinct external vocal sacs as wrinkled skin on throat at the corner of lower jaw.

***Diagnostic characters.* –** *Rana daunchina* is characterized by the following combination of characters: (1) body stocky; (2) SVL of adult males 44 ± 1.5 (40.6–46.8 mm), adult female 50.9 mm; (3) nostril directed laterally; (4) marginal grooves on fingers absent or rarely present; (5) marginal grooves on toes present; (6) mid-dorsal stripe present or absent; (7) external vocal sac present; (8) nuptial pad present on thumb and first finger, formed as one pad; (9) suprabrachial gland present and large; (10) nest construction behavior present; (11) spinules on back absent or few above vent in adult males; (12) spinules on ventrum absent in adult males and females; (13) tibio-tarsal articulation unknown; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I<IV<III; (17) relative length of toes I<II<V<III<IV; (18) pigmented eggs; (19) larval keratodont formula 0:1+1/1+1:1; (20) Calling: 2–3 weak "dune-dune" musical notes.

***Distribution.* –** China (Sichuan Province).

Rana okinavana Boettger, 1895

Rana okinavana Boettger, 1895: 266. [Syntypes: SMF (2 specimens), Bremen Mus.; SMF 5830 (formerly SMF 1047.3a), designated lectotype by Mertens (1967). Type-locality: Liukiu (= Ryukyus), Japan.]

Rana psaltes Kuramoto, 1985: 150. [Holotype: FUE 80320, by original designation. Type-locality: near the Kampira Falls (Urauchi River), Iriomote Island, Ryukyu Islands, Japan. Synonymy by Matsui (2007).]

***Material examined.* –** Japan: Ryukyu Province, Omotadake [NMNS 3430 (4426), 3438 (4455), 3438 (4456), 3466 (4602), 3466 (4603)].

***Taxonomic notes.* –** Recently, an examination of the lectotype and a paralectotype of *Rana okinavana* revealed that the species is identical with *R. psaltes*. Therefore, the name *R. psaltes* is relegated to a subjective junior synonym of *R. okinavana* (see Matsui, 2007). This author stated that *R. psaltes* from Taiwan (Chou, 1994) should be mentioned as *R. okinavana* too.

***Diagnostic characters.* –** *Rana okinavana* is characterized by the following combination of characters: (1) body stocky; (2) SVL of adult males 41.6 ± 1.4 (40–42.8 mm), adult females 46.7 ± 2.9 (44.6–48.8 mm); (3) nostril directed laterally; (4) marginal grooves on fingers present or absent; (5) marginal grooves on toes present; (6) mid-dorsal stripe present; (7) external vocal sac absent; (8) nuptial pad poorly developed, absent on prepollex but present as small pad on median surface of first finger; (9) suprabrachial gland present and elongate; (10) nest construction behavior present; (11) spinules on back absent in adult males and females; (12) spinules on ventrum absent in adult males and females; (13) tibio-tarsal articulation reaching eye center to near nostril; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I<IV<III; (17) relative length of toes I<II<V<III<IV; (18) pigmented eggs; (19) larval keratodont formula 1:1+1/1+1:2; (20) Calling: 17–25 loud, fast-repeated, "gulo" pulses.

***Distribution.* –** Japan (Ryukyu Province).

Rana adenopleura group

Rana adenopleura Boulenger, 1909

Rana adenopleura Boulenger, 1909: 492. [Syntypes: BM ("several specimens"). Type-locality: Fuhacho Village (= Maobu or Wucheng, Nantou County), altitude about 4,000 feet (ca. 1 219 m), Taiwan.]

***Material examined.* –** Taiwan: Fushan Nature Reserve (NMNS 1512-1, 1512-3 to 11, 1512-14 to 23), Horisha (AMNH A 11618-623), Pingtung (MCZ A-125372), Polisia Forosa (CAS 19693–696), Tai-Chung Hsien (Huan-Shan) (AMNH A 68242–243), Yang Ming Mountain (CAS-SUA 20485–487).

***Taxonomic notes.* –** *Rana adenopleura* was described by Boulenger (1909) from four specimens collected at "Fuhacho", Taiwan. Several authors regarded the frogs from continental China belonging to *R. adenopleura* and regarded the congeneric species from Fukien namely *R. caldwelli* as a synonym (Pope, 1931; Liu, 1950; Kuramoto, 1985; Chou, 1999; Orlov et al., 2002). Based on published evidences, Dubois (1992) proposed to keep the name of *R. adenopleura* for Taiwan population and restricted the name of *R. caldwelli* for the Fujian population. As given above, the morphological and morphometrical comparisons confirm the differences between these two species as similar as the proposal of Dubois (1992).

***Diagnostic characters.* –** *Rana adenopleura* is characterized by the following combination of characters: (1) body elongated; (2) SVL of adult males 48.5 ± 2.7 (44.6–53.9 mm), adult females 49.9 ± 1.9 (47.6–52.8 mm); (3) nostril directed laterally; (4) marginal grooves on fingers present or absent; (5) marginal grooves on toes present; (6) mid-dorsal stripe present or absent; (7) external vocal sac present; (8) nuptial pad present on thumb and first finger, forming a single pad; (9) suprabrachial gland present and large; (10) nest construction behavior absent; (11) spinules present on entire dorsum of head and body (in adult males); (12) spinules on ventrum present in adult males; (13) tibio-tarsal articulation reach snout tip or between eye to snout; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I<IV<III; (17) relative length of toes I<II<III=V<IV; (18) pigmented eggs; (19) larval keratodont formula 1:1+1/1+1:2; (20) Calling: 2–4 loud "gai-gai-…" notes.

***Distribution.* —** China (Taiwan).

Rana caldwelli Schmidt, 1925

Rana caldwelli Schmidt, 1925: 2. [Holotype: AMNH 18454, by original designation. Type-locality: "Fukien Province" (probably near Yenping), China.]

***Material examined.* –** China: Fujian Province, Ch'ungan Hsien (AMNH A 29992–997, 30025–042), Yenping (AMNH A 28232–236, 28238–241, 28244, 28527–529, 28531–536, 28538–539), no exactly locality (AMNH A 18572). Sikang Province, Ta-liang-shan (FMNH 49464-466), Chaochiao (FMNH 49460, 49462).

***Taxonomic notes.* —** *Rana caldwelli* was described by Schmidt (1925) based on two specimens from Fujian. He distinguished his new frog from *R. adenopleura* by their more projecting snouts, rougher skin and posteriorly broken up dorsolateral glandular folds. Pope (1931) compared Schmidt's types with his new series of 98 specimens and showed that the characters separating *R. caldwelli* and *R. adenopleura* were not diagnostic and placed *R. caldwelli* in the synonymy of the original species *R. adenopleura*. This consideration was followed in subsequent works (Liu, 1950; Chou, 1999). As results given above, the species *Rana caldwelli* is recognized as valid species as similar to Dubois (1992).

***Diagnostic characters.* –** *Rana caldwelli* is characterized by the following combination of characters: (1) body elongated; (2) SVL of adult males 49 ± 3.2 (43.1–56.1 mm), adult females 51.6 ± 2.3 (47.7–55.4 mm); (3) nostril directed laterally; (4) marginal grooves on fingers present or absent; (5) marginal grooves on toes present; (6) mid-dorsal stripe present or absent; (7) external vocal sac present; (8) nuptial pad present on thumb and first finger, forming a single pad; (9) suprabrachial gland present and large; (10) nest construction behavior absent; (11) spinules on back present only on posterior half of back (in adult males); (12) spinules on ventrum present in adult males; (13) tibio-tarsal articulation reach snout tip; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I<IV<III; (17) relative length of toes I<II<III=V<IV; (18) pigmented eggs; (19) larval keratodont formula 1:0+0/1+1:1; (20) Calling unknown.

***Distribution.* —** China (Fujian and Sikang provinces).

Rana lini Chou, 1999
(Figs. 2, 3 and 4)

Rana lini Chou, 1999: 301. [Holotype: NMNS 3258, by original designation. Type-locality: Jiangcheng Co., 8 km N Jiangcheng, Simao Prefecture, Yunnan Province, China.]

***Material examined.* –** China: Yunnan Province, Honghe Perfecture, Luchun (NMNS 3168 (7325, 7326, 7330, 7341)**.** Laos: Xieng Khouang Province, Pek District, Phonsavan Market (FMNH 256531–532). Thailand: Loei Province, Phu Rue District, Phu Luang Wildlife Sanctuary (FMNH 262578–579, THNHM 08711–716). Phetchabun Province, Nakhon Thai District, Phu Hin Rong Kla National Park (THNHM 13113–118).

***Taxonomic notes.* —** *Rana lini* was described by Chou (1999) based on specimens collected from Simao and Honghe Perfectures, Yunnan Province (China). Seven specimens from Simao Perfecture were designated as holotype (NMNS 3258) and paratypes (NMNS 3190-1 to NMNS 3190-7). Remaining five specimens from Honghe Perfecture (NMNS 3168-1 to NMNS 3168-5) were designated to the "referred specimens". In this study, we examined four specimens from Honghe Perfecture as in specimens studied.

In the original description of *Rana lini* by Chou (1999), some morphological characters are confusing and do not agree with our examination. Chou's (1999: 391) Table 1 provided several comparisons of morphological, acoustical, and behavioral characters of frogs of the subgenus *Nidirana*. Of those, there are two characters (vocal sacs and dermal fold width of 2nd and 3rd fingers) which differ from our observations. The vocal sacs were defined by Chou (1999) in two states: distinct and indistinct. We also defined this character in two states but in different terms (present and absent). If present, the skin of throat at the corner of lower

jaw has wrinkled skin or pouches but if absent, the skin does not have such structures. Chou (1999) observed vocal sacs in *R. chapaensis*, *R. daunchina* and *R. okinavana* (as *R. psaltes*) as indistinct but we observed this character as present (as wrinkled skin) except in *R. okinavana*. Chou (1999) observed presence of inner and outer dermal fold on second and third fingers of all *Nidirana* species. We observed such a skin fold only on the inner sides of second and third fingers. The dermal fold along lateral edge of 5th toe was observed by Chou (1999) as indistinct in *R. chapaensis*, *R. daunchina* and *R. okinavana* (as *R. psaltes*). We observed this character as present in those three species. Chou's (1999: 391) Table 1 listed the dermal fold along lateral margin of 5th toe in *R. chapaensis* as indistinct but in his key to species (Chou, 1999: 398), this species was placed in the group of species which have evident or distinct dermal fold along lateral margin of 5th toe.

As mentioned above, the confusion of some observed characters between the first description (Chou, 1999) and this study lead us to make the description based on the specimen from Thailand as below.

***Diagnostic characters.* –** *Rana lini* is characterized by the following combination of characters: (1) body elongated; (2) SVL of adult males 53.7 ± 4.1 (44.1–57.9 mm), adult females 59 ± 1.6 (57.7–60.7 mm); (3) nostril directed laterally; (4) marginal grooves on fingers present or absent; (5) marginal grooves on toes present; (6) mid-dorsal stripe present; (7) external vocal sac present; (8) nuptial pad present on thumb and first finger, formed as one pad; (9) suprabrachial gland present and large; (10) nest construction behavior absent; (11) spinules on back present on posterior half of back in adult males; (12) spinules on ventrum present in adult males; (13) tibio-tarsal articulation beyond snout; (14) finger tips dilated; (15) toe tips dilated; (16) relative length of fingers II<I<IV<III; (17) relative length of toes I<II<V<III<IV; (18) pigmented eggs; (19) larval keratodont formula 1:1+1/1+1:2; (20) Calling: 5-7 loud "goo-goo-…" notes.

***Description of specimen.* –** THNHM 13117 (field no. Y 0261), an adult male, Phu Hin Rong Kla National Park, Nakhon Thai District, Phetchabun Province, northeastern Thailand. The specimen was collected by Y. Chuaynkern and Permsak Kanishthajata in 17 Jul.2006.

***Size and general aspect.* –** (1) Frog of moderate size (SVL 56.7 mm), body slender.

***Head.* –** (2) Head of moderate size, widely ovate in dorsal view; longer than wide (HW 17.8 mm; HL 23.5 mm; MN 18.8 mm; MFE 14.9 mm; MBE 9.1 mm), flat above. (3) Snout acuminate in dorsal and lateral views, slightly protruding, its length (SL 9.7 mm) longer than horizontal diameter of eye (EL 6.4 mm). (4) Canthus rostralis rounded, loreal region concave, vertical in cross section. (5) Interorbital space flat, wider (IUE 5.2 mm) than upper eyelid (UEW 4.0 mm) and narrower than internarial distance (IN 6.0 mm); distance between front of eyes (IFE 9.4 mm) 1.3 times in distance between back of eyes (IBE 12.2 mm). (6) Nostrils oval, directed posterodorsally, with flap of skin laterally, closer to tip of snout (NS 4.7 mm) than to eye (EN 5.3 mm). (7) Pupil elliptical, horizontal. (8) Tympanum (TYD 5.7 mm) distinct, horizontally oval, 87% of eye diameter; tympanum-eye distance (TYE 2.2 mm) 39% of tympanum diameter. (9) Pineal ocellus present, in middle point between anterior borders of eyelids. (10) Vomerine ridge present, bearing numerous small teeth (N=8 in each side); with an angle

Fig. 2. The adult male specimen (in preservative) of *Rana lini* from Phetchabun Province, northeastern Thailand. THNHM 13117 (field no. Y 0261), SVL 56.7 mm. Scale bar = 20 mm. Photo: Y. Chuaynkern (11 Dec.2007).

of 45° to body axis, closer to choanae than each other, as long as distance between them. (11) Tongue large, cordate; emarginated, bearing no median lingual process. Tooth-like projections on lower jaw absent.

***Forelimbs.* –** (12) Arm short and thin; forearm (FLL 12.4 mm) shorter than hand (HAL 15.1 mm); not enlarged. (13) Finger I and II short and thin; finger III (TFL 9.29 mm) and IV long and thin. (14) Relative length of fingers: I=II< IV<III. (15) Tips of fingers rounded, not enlarged with latero-ventral grooves on finger II, III and IV (without the groove on finger I), slightly wide compared to finger width (fd1 0.9 mm, fw1 0.9 mm; fd2 1.1 mm, fw2 1.1 mm; fd3 1.1 mm, fw3 1.0 mm; fd4 1.2 mm, fw4 1.1 mm). (16) Fingers with dermal fringe on inner side of finger II and III; webbing on fingers absent. (17) Subarticular tubercles prominent rounded or oval, single, all present. (18) Prepollex distinct, oval; two distinct palmar tubercles, larger inner elliptic and smaller outer narrowly elliptic; supernumerary tubercles absent.

***Hind limbs.* –** (19) Hind limbs long; heels overlapping when limbs are folded at right angles to body; tibio-tarsal articulation beyond tip of snout; tibia 4.2 times longer (TL 33.3 mm) than wide (TW 7.9 mm), longer than thigh (FL 30.0 mm) and shorter than distance from base of internal metatarsal tubercle to tip of toe IV (FOL 34.2 mm). (20) Toes long and thin, toe IV (FTL 21.3 mm) 2.3 times distance from base of tarsus to tip of toe IV (TFOL 48.5 mm). (21) Relative length of toes: I<II<III=V<IV. (22) Tips of all toes rounded, enlarged; disks present on toes I-II-III-IV-V, with distinct latero-ventral grooves, rather wide compared to toe width (td1 1.4 mm, tw1 0.9 mm; td2 1.5 mm, tw2 0.9 mm; td3 1.5 mm, tw3 0.8 mm; td4 1.2 mm, tw4 0.8 mm; td5 1.2 mm, tw5 0.8 mm). (23) Webbing present, moderate: I 1½ - 1 II 1 - 2$^{3}/_{2}$ III 1½ - 2 IV 2½ - 1 V (WTF 5.2 mm, WFF 6.6 mm; WI 4.1 mm, WII 5.2 mm; MTTF 14.8 mm, MTFF 15.8 mm, FTTF 17.1 mm, FFTF 15.4 mm). (24) Dermal fringe along toe V present: from tip of toe beyond the first subarticular tubercle until 1/3 of distance between OMT and first subarticular tubercle. (25) Subarticular tubercle prominent, oval or rounded, simple, all present. (26) Inner metatarsal tubercle distinct, elliptic, it length (IMT 2.9 mm) 2.9 times in length of toe I (ITL 8.3 mm). (27) Tarsal folds absent. (28) Outer metatarsal tubercle present, small, rounded; supernumerary tubercles absent; tarsal tubercle absent.

***Skin.* –** (29) Snout, between eyes, side of head and anterior part of back smooth; posterior part of back smooth with densely scatter horny spinules; upper part of flank, to line from insertion of arm to groin granular topped with horny spinules; lower part of flank to line from insertion of arm to groin smooth. (30) Dorso-lateral folds present, flat and narrow, from back of eye to above groin; supratympanic fold absent; parotoid glands absent; cephalic ridges absent; co-ossified skin absent. (31) Dorsal parts of forelimb, thigh and tarsus smooth with few horny spinules, while dense in dorsal part of leg; upper part of foot and toes smooth. (32) Throat, chest, belly and ventral part of anterior part of thighs smooth; posterior part of thigh around vent with tree frog belly skin. (33) Macroglands: distinct rictal gland in posterior corner of mouth; supra-brachial gland present, large nearly rhomboid shape (left: maximum length 12.8 mm, maximum width 7.8 mm; right: maximum length 14.4 mm, maximum width 7.9 mm) from behind 2nd rectal gland to the middle of body; humeral gland absent.

***Colouration (in alcohol).* –** (34) Dorsal parts of head and dorsum brown with creamy stripe from tip of snout to near vent (not reaching above vent), and creamy stripes along inner dorsolateral fold from posterior of eyes to nearly vent, black spots on posterior part of back, denser near vent; upper part of flank brown with black stripe along outer part of dorsolateral fold from posterior of eye to nearly vent, lower part of flank creamy with dark mottled; supra-brachial gland covered with dark fine melanin dots and with dark spot near lower edge of gland; loreal region brown with black stripe from tip of snout across nostril to anterior border of eye, tympanum brown; upper lip pale brown with white stripe running above upper lip from tip

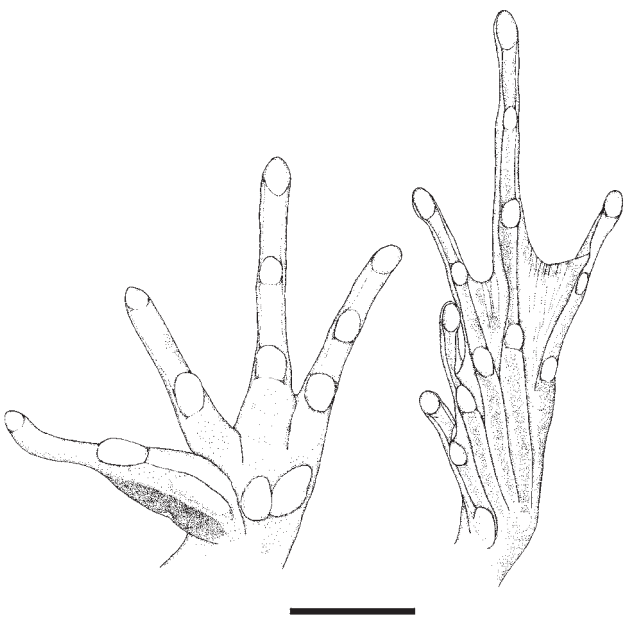

Fig. 3. Ventral views of left hand and foot of adult male *Rana lini* (THNHM 131117) from Phetchabun Province, northeastern Thailand. Scale bar = 30 mm.

Fig. 4. Life photo of female *Rana lini* from Loei Province, northeastern Thailand (THNHM 08711, with SVL 53 mm). Photo: Y. Chuaynkern (12 Aug.2005).

of snout to rectal glands; dorsolateral fold brown in inner part and black in outer part. (35) Dorsal part of forelimb creamy brown with black oblique crossbars; dorsal part of thigh, tibia, and tarsus creamy brown with narrow black oblique crossbars; posterior part of thigh cream with black vermiculation. (36) Throat, vocal sac, chest, belly and tibia cream, margin of throat cream with feebly creamy brown spots; anterior part of thigh cream and posterior part creamy yellow; tarsus cream with few brown pigmented; webbing on both sides brown.

***Colouration in life.* –** Dorsal parts of head and back brown with creamy vertebral stripe from tip of snout to nearly vent (broken in posterior part of back before vent), and creamy stripes along inner side of dorsolateral folds from tip of snout to nearly vent, black spots on posterior part of back, more densely set near vent; upper flank yellowish brown with black stripe extended from posterior eyelid to groin, few black spots above area of supra-branchial gland, supra-branchial gland yellowish brown with feebly dark vermiculation; lower part of flank light yellowish brown with grey vermiculation, more distinguished in posterior of lower flank; loreal region brown with black stripe from tip of snout across nostril to anterior border of eye; tympanum brown and tympanum region yellow; upper lip yellow with few creamy white spots, creamy white stripe from tip of snout to mouth corner, lower lip yellow with creamy white spots; dorsolateral fold whitish brown in inner part and black in outer part. Dorsal part of forelimb brown with two dark brown oblique bands on upper arm and three on lower arm; dorsal part of thigh brown with dark brown oblique crossbars; dorsal part of tibia pale brown with five to six dark brown bands on anterior part; tarsus pale brown with three feeble dark brown bands; dorsal part of foot brown; posterior part of thigh with yellowish brown and dark brown labyrinthine blotches arranged in a longitudinal way on upper portion and with gray vermiculation in lower portion. Throat, chest, anterior belly and ventral part of forearm creamy white, posterior belly creamy yellow, ventral part of thigh pinkish and reddish, tibia and tarsus creamy yellow.

Fig. 5. Habitat of *Rana lini* from Phu Hin Rong Kla National park (location 47 Q 0714929 UTM 1878834, altitude 1,300 m), Nakhon Thai District, Phetchabun Province. Photo: Y. Chuaynkern (16 Jul.2006).

***Male secondary characters.* –** (37) A single nuptial pad present (not separated into two pads), covering lateral surface of thumb and edge of prepollex continued to covering dorsal surface of finger I to level of distal edge of subarticular tubercle; cream coloured spines. (38) Vocal sacs present, distinct on throat; a pair of slit-like openings at posterior of jaw. (39) Other secondary sexual characters: humeral glands absent, suprabrachial gland present.

***Natural history notes.* –** The specimens from Phu Hin Rong Kla National Park (Nakhon Thai District, Phetchabun Province) were caught in a permanent pond (location 47 Q 0714929 UTM 1878834, 1,300 m asl) which has drainage conduit to move out water from the pond (Fig. 5). The frogs were sitting on water plants and calling. Several frogs from Man Daeng Protected Unit (location 47 Q 0718477 UTM 1872542, 1,647 m asl) were sitting on the bank of an artificial pond and were also calling. The calls of the frogs were heard in the daytime also. Specimens from Phu Luang Wildlife Sanctuary (Phu Rue District, Loei Province) were caught in Pine forest at approximately 1,500 m asl. These frogs are not utilized for food.

Fig. 6. Map showing localities of recent distribution of *Rana lini* (solid circles) and *R. chapaensis* (solid squares) from this study and literature. 1 = Simao Prefecture (type locality of *R. lini*), Yunnan Province (China); 2 = Honghe Prefecture, Yunnan Province (China); 3 = Pek District, Xieng Khouang Province (Laos); 4 = Phu Luang Wildlife Sanctuary, Phu Rue District, Loei Province (Thailand); 5 = Phu Hin Rong Kla National Park, Nakhon Thai District, Phetchabun Province (Thailand); 6 = Xe Sap National Biodiversity Conservation Area, Samoy District, Saravan Province (Laos); 7 = Sa Pa (type locality of *R. chapaensis*), Lao Cai Province (Vietnam); 8 = Huong Son, Ha Tinh Province (Vietnam).

***Distribution.* –** China (Yunnan Province); Laos (Xieng Khoaung Province); Thailand (Loei and Phetchabun provinces).

Rana pleuraden group

Rana pleuraden Boulenger, 1904

Rana pleuraden Boulenger, 1904: 131. [Syntypes: BM. Type-locality: Yunnan Fu (altitude about 6,000 feet), Yunnan, China.]

***Material examined.* –** China: Linjei Province, Dapinjung [NMNS 3694 (12743), 3694–12, 3694–17, 3694–19]. Yunnan Province, Likiang (AMNH A 5780–781, 5783–784, 5787, FMNH 7533–534, 7536), Nanking (Baoshan Perfecture) (CAS 207510–515), North of Likiang (FMNH 15163), Nujiang (CAS 228152–155), Tongchuan Fu (MCZ A-7183), Wuting Chow (AMNH A 6528, 6591–592), Yunnanfu (AMNH A 5286–287, 5427, 5436–437, 5763, 13451–452, 30860–870, CAS 54653, FMNH 7539, 7541–542, 24628, 24630, 24632), Yunnanfu [Kunming] (MCZ A-7615–619, A-7621–622), Yunnanfu [Kunming Shi] (MCZ A-8146–148, A–9616).

***Taxonomic notes.* –** Since the species *Rana pleuraden* was described from Yunnanfu in 1904 by Boulenger, the taxonomic status of this species is undoubted due to the morphological characters are striking differences from other species of *Nidirana*.

***Diagnostic characters.* –** *Rana pleuraden* is characterized by the following combination of characters: (1) body elongated; (2) SVL of adult males 50.5 ± 3.1 (45.4–58.7 mm), adult females 53.4 ± 4.4 (47.5–60 mm); (3) nostril directed dorsally or upward; (4) marginal grooves on fingers absent; (5) marginal grooves on toes absent; (6) mid-dorsal stripe present or absent; (7) external vocal sac present; (8) nuptial pad present on thumb and first finger, formed as one pad; (9) suprabrachial gland present and large; (10) nest construction behavior absent; (11) spinules on back present on posterior half of back in adult males; (12) spinules on ventrum present in adult males; (13) tibio-tarsal articulation reaching between eye to snout; (14) finger tips not dilated; (15) toe tips not dilated; (16) relative length of fingers I<II<IV<III; (17) relative length of toes I<II<V<III<IV; (18) pigmented eggs; (19) larval keratodont formula unknown; (20) Calling: 4–7 loud "guo-guo-…" notes.

***Distribution.* –** China (Linjei and Yunnan provinces).

DISCUSSION

In this study, morphological and morphometrical comparisons separated the species of *Nidirana* into three groups including of *Rana okinavana* group (*Rana chapaensis*, *R. daunchina* and *R. okinavana*); *Rana adenopleura* group (*R. adenopleura*, *R. caldwelli*, *R. lini*, the specimens form Laos and Thailand); and *Rana pleuraden* group (*R. pleuraden*). This result also confirms the uniqueness of this taxon. The separation of these frogs into three groups is quite similar to group proposed by Dubois (1992). He grouped the frogs of *Nidirana* into two groups as *Rana adenopleura* [includes *R. adenopleura*, *R. caldwelli*, *R. chapaensis*, *R. daunchina* and *R. psaltes* (as *R. okinavana*)] and *Rana pleuraden* groups [includes *R. pleuraden*]. Our comparisons further separated the *Rana adenopleura* group of Dubois (1992) into two groups as mentioned above. These three groups exhibit different morphological and behavioral characters. The species in *R. chapaensis* groups possess the nest construction behavior (Table 1). This behavior is absent in both of *Rana adenopleura* and *Rana pleuraden* groups. The species *R. lini* from Thailand (Phu Hin Rong Kla National Park, Phetchabun Province) should not have the nest construction behavior. Six adult males were collected in the pond while they were calling but their nests were not found. *R. chapaensis*, who shows nest constructing behaviour, is calling at the edge of ponds or in marshy meadows, and can be found sitting in a small pit made of earthy material and containing some water (Annemarie Ohler, unpublished observation). So calling position of adult male is distinct.

The species *Rana caldwelli* was placed in the synonymy of *R. adenopleura* by Pope (1931). Subsequent works were agreed with Pope (1931) as in Liu (1950), Zhao & Adler (1993), and Chou (1999). However, this species was removed from the synonymy of *R. adenopleura* by Dubois (1992). The proposal of Dubois (1992) to revalidate this species was confirmed by morphological and morphometric data as presented in the results.

Prior to our study, *Rana adenopleura* and *R. chapaensis* were listed from Thailand (see Chan-ard et al., 1999; Khonsue & Thirakhupt, 2001; Chan-ard, 2003; Nabhitabhata & Chan-ard, 2005). The frog referred to *R. adenopleura* by Chan-ard et al. (1999) and Khonsue & Thirakhupt (2001) are the same frogs because Khonsue & Thirakhupt (2001) followed Chan-ard et al. (1999) and included *R. adenopleura* to their checklist. The frogs called *R. adenopleura* by Chan-ard et al. (1999) came from Phu Luang Wildlife Sanctuary (Loei Province) (Chan-ard, per.com, 12 December 2007) and were later reported as *R. chapaensis* by Chan-ard (2003) and Nahbitabhata & Chan-ard (2005). Thus the previous names of those frogs (*R. adenopleura* and *R. chapaensis*) were assigned for the same population from Loei Province. Therefore, based on external morphological and morphometrical data, these specimens were re-allocated to *R. lini* in this work. This assignment documented the first country record of this species in Thailand. We also propose here the relegation of *R. adenopleura* and *R. chapaensis* from the list of amphibian fauna of Thailand. The status of *R. adenopleura and R. chapaensis* as evaluated by Nabhitabhata & Chan-ard (2005) was transferred to *R. lini;* its status should be revised in the future.

As for Laos, the specimens referred to *Rana chapaensis* from Xieng Khouang Province (see Stuart, 2005) were re-assigned to *R. lini* as the specimens from Thailand. Therefore, this assignment documented the first country record of this species in Laos. The status of *R. lini* in this country should be revised in the future as well. Based on this work, we

confirm *R. chapaensis* and *R. lini* as member of the fauna of this country.

Our allocation of the Laos and Thai specimens of *Nidirana* to *Rana lini* is based on external morphological characters. It is very difficult to differentiate those specimens from *R. lini* based on information available. Moreover our statistical analysis is limited because of the low number of specimens available (Dubois, 1984) referable to the species *R. lini*. So further data based on more specimens, topotypical specimens and using various methods (e.g., molecular, acoustic, tadpole) will be necessary to confirm or refuse our conclusion. In addition, the type specimens of *R. lini* Chou, 1999 were not available in this study. Comparison to the type specimens is recommended for further investigation.

Considering the limited number of specimens available, the systematic and distribution of species of *Nidirana* should be submitted to further investigation. Many species were reported from various countries but, unfortunately, the voucher specimens were not available for this work. Reports of *Rana adenopleura* (Chan-ard et al., 1999; Khonsue & Thirakhupt, 2001; Nabhitabhata & Chan-ard, 2005) and *R. chapaensis* (Chan-ard, 2003) in Thailand were reviewed and clarified as well as the report of *R. chapaensis* from Laos (Stuart, 2005). The identity of *R. chapaensis* in Vietnam is undoubted (Bourret, 1937; Ohler et al., 2000) and specimens have been studied here. However, the record of *R. adenopleura* from northern Vietnam provided by Orlov et al. (2002) is doubtful. Information on distribution was obtained from literature (i.e. Pope, 1931; Liu & Hu, 1961; Liu et al., 1973; Matsui & Utsunomiya, 1983; Frost, 1985; Kuramoto, 1985; Dubois, 1992; Zhao & Adler, 1993). When considering these works in detail, no specimen information on the Vietnam record was provided. Therefore, further investigation on the occurrence of this taxon is also recommended. According to our study, this should not be *R. adenopleura* but might be *R. daunchina* or *R. lini*.

To date, the classification and taxonomic status of species of subgenera *Nidirana* and *Babina* Thompson, 1912, still need re-evaluation even though their status has been discussed fairly intensively (Boulenger, 1892; Thompson, 1912; Van Denburgh, 1912a,b; Boulenger, 1917, 1918; Inger, 1947; Nakamura & Ueno, 1963; Okada, 1966; Dubois, 1981; Inger et al., 1990; Dubois, 1992; Chen et al., 2005; Frost et al., 2006; Matsui, 2007; Stuart, 2008). As Frost et al. (2006) placed these genera in the same genus, namely *Babina*, but the morphology of these genera are distinct and there is also differences in body-size (see Inger, 1947, and Maeda & Matsui, 1990). As stressed by Dubois & Ohler (2001) and Dubois et al. (2001), "body shape" is one of the good clues for indication of adaptive niche and thus measuring the ecological criterion for generic classification. Therefore, this criterion should attire attention as well as other criterions. Moreover, phylogenetic relationship inferred from various information i.e., molecular, external and internal morphology, skeleton, muscles, tadpole, ecological or behaviour is still needed on a larger sample of species. In addition, study of morphological and molecular variations within population, species or between species should complete our knowledge on these frogs and will be useful for aspect such as taxonomy and conservation.

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