TAXONOMY AND ECOLOGY OF AMPHIBIAN COMMUNITIES IN SOUTHERN VIETNAM: LINKING MORPHOLOGY AND BIOACOUSTICS

TRAN, THI ANH DAO

Taxonomy and ecology of amphibian communities in Southern Vietnam: Linking morphology and bioacoustics

Dissertation

zur

Erlangung des Doktorgrades (Dr. rer. nat.)

der

Mathematisch-Naturwissenschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

vorgelegt von

TRAN, THI ANH DAO

aus

Ho Chi Minh City, Vietnam

Bonn, 2013

Angefertigt mit Genehmigung der Mathematisch-
Naturwissenschaftlichen Fakultät der
Rheinischen Friedrich-Wilhelms-Universität Bonn

1. Gutachter Prof. Dr. Wolfgang Böhme

2. Gutachter Prof. Dr. Wolfgang Wägele

Tag der Promotion:03/12/2013

Erscheinungsjahr: 2014

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

BDNB NP	Bidoup Nui - Ba National Park, Lam Dong Province, Vietnam
CYS NP	Chu Yang Sin National Park, Dak Lak Province, Vietnam
PB NP	Phuoc Binh National Park, Ninh Thuan Province
SLSM	Song Luy and Song Mao watershed forests, in Binh Thuan Province, Vietnam
TD NR	Ta Dung Nature Reserve, Dak Nong Province, Vietnam

CHAPTER I. INTRODUCTION

1. Background

1.1. Amphibian communities in Vietnam: divers but poorly known

The knowledge about the actual diversity of amphibians in Vietnam is still imperfect although many researches that focus on the herpetofauna of this country have been intensive in recent years. The number of species has been strikingly increased during the last two decades. The Vietnamese amphibian fauna provided by Inger et al. (1999) included 100 species, that is approximately 20% higher than the species number (78) documented by Bourret (1942). Nguyen and Ho (1996) listed a total of 82 species. Six years later, Orlov et al., (2002), summarized the diversity of amphibians in Vietnam with 147 species. Nguyen et al. (2005) recorded a total of 162 amphibian species for Vietnam. In the most recent checklist, Nguyen et al. (2009) reported 177 species of amphibians for this country. The species number of amphibians from this country raised to 181 in 2010 (see Ziegler & Nguyen, 2010) and new discoveries have been continuous in the last three years (Ohler et al., 2011; Rowley et al., 2011a; 2011b; Stuart et al., 2011; Nishikawa et al., 2012; Orlov et al., 2012; Rowley et al., 2012a; 2012b; Nguyen et al., 2013a; Nishikawa et al., 2013) (Figure 1). Molecular analyses combined with other methods such as morphology, bioacoustics, monitoring could help scientists to understand the taxonomy and evolution of amphibians (Cocroft & Ryan, 1995; Brown & Stuart, 2012). Many species were newly discovered or reassigned based on molecular phylogeny evidence (Biju et al., 2010; Li et al., 2011; Orlov et al., 2012; Yu et al., 2013). In consequence of such work, geographic distribution of amphibian species becomes a new issue for herpetologists and still requires more research. Moreover, batrachian fauna of Vietnam, comprises of many complex and taxonomically uncertain species (Nguyen et al., 2009; Orlov et al., 2012). In addition, the research on natural history of Vietnamese amphibians is still limited (Ziegler et al., 2008; Ziegler & Nguyen, 2008).

1.2. History of the research on the batrachian fauna of Langbian Plateau and adjacent areas

Langbian Plateau belongs to the herpetological subregion Southern Annamites (or Truong Son Range in Vietnamese) of Indochina (Figure 2, Bain & Hurley, 2011). There were only few herpetological publications for this area. The first paper about the herpetofauna of southern Vietnam, documented by Malcom A. Smith in 1921, described five new species from the Langbian Plateau and provided accounts for four other anurans. The second paper was published in 1924 and Smith reported 11 species of Rhacophoridae from Indochina and Malaysia, including seven new species, six of them being discovered from the Langbian Plateau and neighboring areas (Smith, 1924). The comprehensive book of Bourret, published in 1942, provided accounts and descriptions of amphibians in Indochina (Cambodia, Laos, and Vietnam) with records of 19 species of amphibians from the Langbian Plateau. Anderson (1942), described a new species (*Microhyla fusca*) and recorded five other species from Da Lat (Lam Dong Province).

Data about amphibian fauna of southern Vietnam was still poorly known until 1998, when Amy Lathrop et al., (1998) described two new species (*Leptobrachium xanthospilum*, *Leptobrachium banae*) from Kon Tum Plateau based on collections obtained from surveys during period between 1996 and 1998. Inger et al (1999), provided data of 50 anuran species in the Kon Tum Plateau including twelve new records for Vietnam, and six new species from this area (*Leptolalax tuberosus*, *Amolops spinapectoralis*, *Hylarana attigua*, *Philautus abditus*, *Kurixalus baliogaster*, and *Rhacophorus exechopygus*). In the checklist of amphibians of Vietnam compiled by Orlov et al (2002), 40 species were recognized, comprising 19 species from the Langbian Plateau and 38 species from the Kon Tum Plateau. During the last decade, a number of new amphibian species had been found in the Kon Tum Plateau, for example *Leptobrachium ngoclinhensis* (Orlov, 2005), *Odorrana gigatympana* and *Theloderma ryabovi* (Orlov et al., 2006a; 2006b), as well as *Rhacophorus marmoridorsum* (Orlov, 2008).

In the book “Herpetofauna of Vietnam”, Nguyen et al (2009) provided a list of 67 (among 177 in the total) species of amphibians from the Langbian Plateau. Recently, integration of morphological, acoustic, and molecular methods is a useful tool to resolve the taxonomic problems of many anuran groups, especially cryptic or widespread species. Among 18 new amphibian species found in the last four years (between 2010 and 2013), 11 were discovered from the Langbian and Kon Tum plateaus (Rowley et al., 2010b; 2010d; Ohler et al., 2011; Rowley et al., 2011a; 2011b; Stuart et al., 2011; Nishikawa et al., 2012; Orlov et al., 2012; Rowley et al., 2012a; 2012b; Nguyen et al., 2013b).

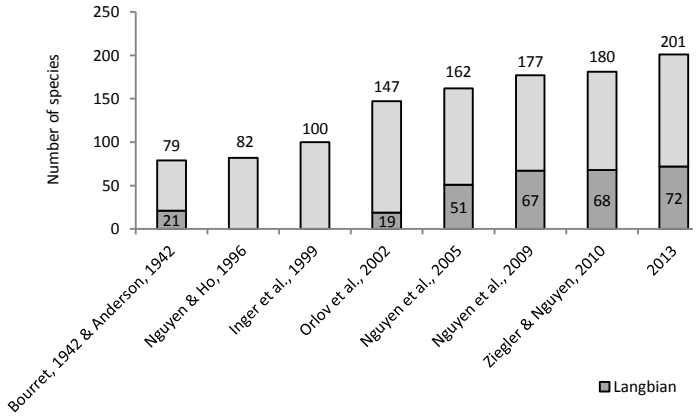

Figure 1. Number of amphibian species known from Vietnam and Langbian Plateau during last 70 years

In Cambodia, the eastern uplands in Mondulkiri, Ratanakiri, and Stung Treng provinces are considered as the western slopes of the Langbian and Kon Tum plateaus of Vietnam (Stuart et al., 2006; Sterling et al., 2007). According to Stuart et al., (2006), the amphibian fauna of the eastern hills of Cambodia has a high similarity with that of central mountains of Vietnam rather than with those of other highlands of Cambodia.

Species richness of amphibians in the Langbian Plateau seems to be underestimated. This area is one of two subregions that have least survey efforts in Vietnam (Table 1). There were totally only 23 surveys obtained for the subregion Southern Annamites, only about one-third of those conducted in the neighboring subregion, Central Annamites, or in the subregion that has a nearly equivalent area, Northeast Uplands (Bain & Hurley, 2011).

Table 1. Species richness and survey numbers in terrestrial herpetological subregions in Vietnam.
(Locations of the subregions are shown in Figure 2; Data source: Bain & Hurley, 2011).

Subregion	Northeast Uplands (NEU)	Northeast Lowlands (NEL)	Northern Annamites (NAN)	Central Annamites (CAN)	Southern Annamites (SAN)	Central-south Vietnam Lowlands (CSL)	Mekong Delta (MEK)
Area (km^2)	18084	94798	46951	41774	26612	56305	69896
Number of surveys	70	94	49	68	23	13	43
Number of species	69	44	63	77	46	48	21
Number of endemic species	16	5	19	36	17	12	2

1.3. Overview about anuran bioacoustic research

Anuran vocalizations could be primarily classified in four kinds of calls: (1) advertisement call; (2) reciprocation call; (3) release call; and (4) distress call (Duellman & Trueb, 1994; Wells, 2007). Among these categories of calls, advertisement call is the best known because of its important role in the life of anurans. Advertisement calls, also known as mating calls or breeding calls that consist of information of signaler's species and individual identifications, sizes, and locations, are produced by males for mainly attracting conspecific females and announcing their territories with other conspecific males (Duellman & Trueb, 1994; Kelley, 2004; Narins et al., 2007).

Structures of vocal signals differ depending on species, individuals, and environmental conditions including physical factors and community interactions. Evidence from studies indicated that

temperature has effects on call rate, call duration, pulse rate, pulse duration, and dominant frequency of calls in some anuran species (Gerhardt & Huber, 2002; Narins et al., 2007). Clues of relationship between acoustic characters and body size of calling individual were found from previous acoustic reports (Gerhardt & Huber, 2002; Hauselberger & Alford, 2005; Briggs, 2010).

Many anuran species have behavioral aggregation for making choruses and breeding (Duellman & Trueb, 1994; Narins et al., 2007; Wells, 2007). In choruses, background noise can mask signals of individual callings and affect on abilities of recognizing the acoustic signals of females (Narins et al., 2007; Wells, 2007). Thus, the calling males adjust their signals in different ways in order to cope with competitions from their neighbors and the loud background noise. In some species, males tend to be aggressive toward other males in a chorus (Narins et al., 2007). The frogs change or add more information into their calls and make the calls change in some features such as length of duration, repetition rate, number of notes, or introduce new types of notes in their calls (Duellman & Trueb, 1994; Gerhardt & Huber, 2002; Narins et al., 2007; Wells, 2007). Terms used for this kind of calls are aggressive calls or territorial calls (Wells, 2007). The most common response to calling neighbors in anurans is a rising in duration or rate of call in comparison with single calling (Gerhardt & Huber, 2002). The calling males also change in other characteristics of the calls such as dominant frequency and intensity (Narins et al., 2007; Wells, 2007).

Vocalization provides efficient approaches for studies on biology of anurans. Many behavioral activities in mating and reproduction in anurans were figured out based on vocal studies (Gerhardt & Huber, 2002; Kelley, 2004; Narins et al., 2007; Wells, 2007). Tungara frogs (*Engystomops*) are well known examples for acoustic communication studies (Kelley, 2004; Ron, 2008). Acoustic signals are also an useful technique for taxonomic study because of its species-specific characters and relationship between the acoustic signals and calling individual's morphological features such as vocal sac and trunk muscles (Gerhardt, 1994; Wells, 2007). The number of new species descriptions that employed acoustic data, combined

with morphological and/or molecular data has been continuously increased in the last three decades, especially since 2000 (Brown & Stuart, 2012). Data from audio signals could be also used for estimating species richness and abundance of anuran populations (Royle & Link, 2005; Canavero et al., 2008). Evidence of environmental effects on acoustic signals provided data for assessing relationships between or among populations or species (Gerhardt & Huber, 2002). Monitoring of anuran populations could be conducted based on call surveys as well (Crouch & Paton, 2002; Royle & Link, 2005).

Most of the studies on Vietnamese amphibians focused on taxonomy based on distributional and morphological data until in recent years the works on acoustic and molecular analyses emerged. Beside recent new descriptions that used bioacoustics as taxonomic approach, there were only few anuran vocal studies published from Vietnam, which in addition mostly referred to anurans from the North and Center of the country (Trepanier et al., 1999; Ziegler, 2002; Ohler & Grosjean, 2005; Wildenhues et al., 2011).

1.4. Objectives of the research

The focal aim of this study is to investigate the community of amphibians in Langbian Plateau, the southernmost highlands of Vietnam. Specific objectives of this study are: (1) to inventory species richness of the amphibian fauna of the Langbian Plateau; (2) to analyze advertisement calls of amphibian species with special focus on the poorly known or complex species; (3) to provide novel data on natural history of amphibian species in the study area; (4) to discuss the biogeographic relationships of the amphibian fauna of the Langbian Plateau with adjacent areas; and (5) to discuss major threats to the amphibian community in the study area.

2. Study area

2.1. Topography

The topography of Vietnam, generally, consists of mountainous and lowland patterns. North of Vietnam is characterized by mountains at

elevations between 300−1600 m, in the Northeast; Hoang Lien Son Range, in the Northwest; and the Red River Delta located only 2−6 m above the sea level, in the Southeast. Central Vietnam has features of Truong Son Range and coastal lowlands. The southern part of the country is well known with the lowland of Mekong Delta, with an average elevation at under ten meters above sea level (Averyanov et al., 2003; Sterling et al., 2007).

Truong Son Mountains is the Vietnamese part of Annamite Range, the main uplands in Indochina, spreading over Laos, Vietnam, and Cambodia, from Northwest to Southeast (Bain & Hurley, 2011). The Truong Son Mountains run from Nghe An Province to Da Nang City, along boundary between Vietnam and Laos, with few peaks reaching 1300 m. This Chain is continued by Kon Tum Massif, with elevations above 500 m, the highest peak at Ngoc Linh Mount (2598 m) and joining the lower uplift of Pleiku Plateau, at about 800−1400 m of elevations, in Gia Lai Province (Averyanov et al., 2003; Sterling et al., 2007).

The study site is Langbian Plateau, also known as Lang Bian, Da Lat or Lam Vien Plateau and it is also considered as the southern termination of the Truong Son Range (Figure 2). This is the isolated, large, and southernmost highland

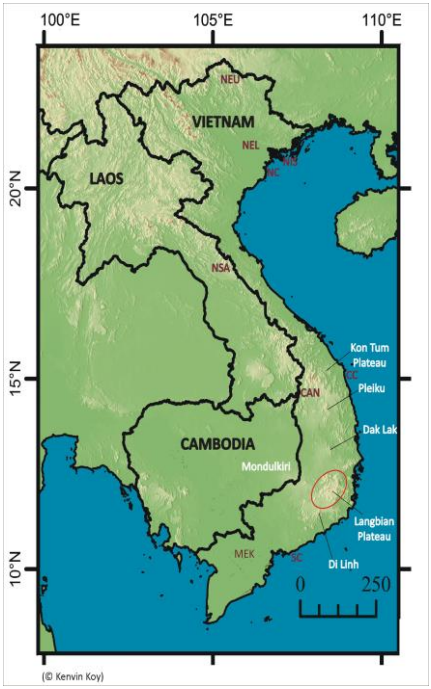

Figure 2. Map showing the study site, Langbian Plateaus, and other terrestrial herpetological sub-regions in Vietnam.

in Vietnam (Birdlife, 2001a; Averyanov et al., 2003; Sterling et al., 2007; Bain & Hurley, 2011). Separated from south of the Kon Tum Massif by Pleiku and Dak Lak highlands, Dak Lak Province, the Langbian Plateau extends southwestward and connects to Di Linh Plateau, Lam Dong Province, slopes eastward into coastal lowlands in Ninh Thuan and Khanh Hoa provinces, and its western tie reaches to highlands in Mondulkiri Province, eastern Cambodia (Sterling et al., 2007; Bain & Hurley, 2011).

In general, the Langbian Plateau is formed from basaltic, quartzite, and granite composites and located at elevations 800−2400 m, with some peaks reaching above 2000 m, the highest peak is Chu Yang Sin Mount (2410 m), in Dak Lak Province (Sterling et al., 2007; BirdLife, 2010; Bain & Hurley, 2011; Nguyen & Kuznetsov, 2012). The southern plateau of Di Linh dominates at lower elevation about 1000−1500 m (Sterling et al., 2007). The highlands in Mondulkiri Province of Cambodia lie at elevations between 109−1078 m (Stuart et al., 2006).

2.2. Climate

According to Averyanov et al., (2003), climate of Vietnam falls into one of seven types: (1) Monsoon tropical climate with cold winter and summer rains; (2) Monsoon tropical climate with cold winter and summer-autumn rains; (3) Monsoon tropical climate with warm winter-autumn-winter rains; (4) Monsoon tropical climate with warm winter and autumn-winter rains; (5) Monsoon tropical climate with warm winter and summer rains; (6) Monsoon subequatorial climate with summer rains; and (7) Monsoon tropical climate associated with mountains. Central of the Langbian Plateau has the last climate pattern, with winter dry season, lasting 1−2 months and an annual average rainfall of over 2000 mm, at elevations above 1000 m (Sterling et al., 2007). The average annual rainfall and average temperature, recorded from Da Lat Station, Lam Dong, at elevation of 1513 m, were 1865 mm and 18.2^{o}C, respectively (Nguyen et al., 2000). Dew and fog are common in the dry season (Averyanov et al., 2003). Eastern slope of the Plateau has no dry season and a higher annual rainfall of 3850 mm (Sterling et al., 2007). Marginal areas of the Plateau are belonging to zone of

"Monsoon tropical climate with warm winter and summer rains", with an annual average rainfall from 1500 to 2339 mm per year, at elevations 660−1000 m and the dry season lasting maximum for three months (Nguyen et al., 2000; Averyanov et al., 2003). Average annual temperatures of these regions range between 22−25^{o}C. The lowland areas surrounding the Langbian Plateau have an annual average rainfall of 1500−3000 mm (Sterling et al., 2007).

2.3. Vegetation types

Vegetation of Vietnam is belonging to the Indochinese Floristic Region, including six zones: Sikang-Yunnan, South Chinese, North Indochinese, Central Annamese, South Annamese, and South Indochinese (Averyanov et al., 2003). Within the South Annamese Floristic zone, the Langbian Plateau experiences primarily montane evergreen forests. The evergreen broad-leaved forests grew at elevations between 700−1500 m, with canopies reaching up to 35 m in height, lower layers provided by trees about 15−25 in height and well developed shrubs. Coniferous forests developed on areas at elevations above 1500 m, forming a mixture of evergreen broad-leaved and coniferous forests, with canopies up to 45 m in height, provided by species of Fagaceae, Lauraceae, Magnoliaceae, Theraceae, and Pinus. Two (*Pinus dalatensis & P. krempfii*) of the four main coniferous (*Fokienia hodginsii*, *P. wangii*, *P. dalatensis & P. krempfii*) are restricted to this region (Averyanov et al., 2003; Sterling et al., 2007). Cloud forests occupy areas of high mountains, at elevations above 1800 m, under conditions of moist cloud and exposed to humid winds (Averyanov et al., 2003; Sterling et al., 2007; BirdLife, 2010; Nguyen & Kuznetsov, 2012). Open coniferous woodlands dominated by *Pinus kesiya* are common on hill slopes, at elevations between 1000−1800 m in this region. These woodlands are considered as results of human impacts on the montane forest in the region (Averyanov et al., 2003). Secondary vegetation develops on low elevation and cultivated areas (Sterling et al., 2007).

2.4. Vertebrate fauna in brief

The Langbian Plateau provides accommodation for at least 65 species of mammals (Birdlife, 2010) and many of them are listed by IUCN: five species (Sunda Pangolin *Manis javanica*, Black-shanked Douc Langur *Pygathrix nigripes*, Yellowcheeked Crested Gibbon *Nomascus gabriellae*, Giant Muntjac *Muntiacus vuquangensis*, hog deer *Axis porcinus*) are listed as endangered; five species (Northern Pig-tail Macaque *Macaca leoninae*, Bear Macaque *Macaca arctoides*, Sun Bear *Helarctos malayanus*, Owston's Banded Civet *Chrotogale owstoni*, Gaur *Bos gaurus*) are listed as vulnerable, and four species (Large Indian Civet *Viverra zibetha*, Asiatic Golden Cat *Pardofelis temminckii*, Chinese Serow *Capricornis milneedwardsii*, Chinese Serow *Capricornis milneedwardsii* are listed as nearly threatened (Le & Tran, 2000; Birdlife, 2001a; Hoang et al., 2010; Birdlife, 2010; IUCN, 2012).

A list of 250 species of birds was reported from Chu Yang Sin National Park in recent surveys which reflects an enriched avifauna of the Langbian Plateau (Birdlife, 2010). This Plateau is also defined as an Endemic Birds Area in Vietnam with presences of eight Restricted - Range Birds (*Rheinardia ocellata*, *Jabouilleia danjoui*, *Garrulax millet*, *G. vassal*, *G. yersini*, *Crocias langbianis*, *Sitta solangiae*, and *Carduelis monguilloti*), including six Important Bird Areas namely Chu Yang Sin, Bidoup, Lang Bian, Cong Troi, Tuyen Lam, and Phuoc Binh Mountains (Birdlife, 2001b).

According to Bain and Hurley (2011), in herpetological respect, the Langbian Plateau is within the subregion Southern Annamites of Indochina. This subregion ranks eighth in Indochina for species richness and second for endemic species, after the contiguous subregion Central Annamites. Species number of amphibians recorded from this subregion is 46 (21.90 % total number species reported from Indochina). Of 142 amphibian and reptile species reported from the subregion Southern Annamites, 36 species (25.35%) are restricted to Indochina and 17 species are restricted to the subregion Southern Annamites (Bain & Hurley, 2011).

Information about fresh water fishes and other animals are still deficient. At least 81 species belonging to 56 genera and 18 families

of freshwater fishes have been recorded from the Langbian Plateau (Birdlife, 2001a; 2010).

2.5. Threats to the biodiversity

Decline of biodiversity in Vietnam has been noticed since 1990 and this trend seems not to have changed in current years. Number of threatened species of plants and animals of Vietnam was increased double, from 245 in the year 2000 to 512 in the year 2012 (Birdlife, 2001b; IUCN, 2012). Reasons of the decline status were mainly overexploiting natural resources, habitat loss and fragmentation that are associated with alternating of land use (Sterling et al., 2007). Hunting, fishing, logging, and collecting of plants and animals were routine activities of local ethnic people for long time ago. These activities did not threat to natural resource until recent years, when the use of wildlife products that were only for food and daily consumption of the local people have been changed for trading because of their high-values (Le & Mahood, 2008). Many species of animals and plants were harvested and supplied to markets for meeting demands of timber, food, medicine, decoration, and pets (Sterling et al., 2007; Le & Mahood, 2008). Results from surveys in Chu Yang Sin National Park, in 2007 and 2009, showed that the local people, sometimes, had to illegally hunt or log for paying their debts not for current daily needs as before and level of wildlife and timber trades in and near to buffer zone of the Park was rapidly raised up (Birdlife, 2010). Other factors that caused raising of overexploiting the natural resources in the Langbian Plateau were developing of hunting and harvest techniques and influx of ethnic immigrants from other regions into buffer zones of protected forests (Le & Mahood, 2008; Birdlife, 2010). Forest loss and fragmentation are consequence of developing agriculture and infrastructure activities. Many new roads were established for improving transportation systems in the Langbian Plateau and neighboring regions. A new road from Da Lat to Nha Trang, running through Bidoup - Nui Ba National Park and separating this Park into two parts was an obvious example of forest fragmentation by this kind of activity (Birdlife, 2010). An area of around 100 ha of damaged forest involved with a hydropower

plant establishment within the Chu Yang Sin National Park, in 2007 was estimated by Birdlife (2010). Another 120 ha of destroyed forest was also estimated because of the construction of patrolling road system that pass through the Chu Yang Sin National Park (Birdlife, 2010).

CHAPTER II. METHODS AND MATERIALS

1. Sampling and field data collecting

1.1. Survey sites

Survey sites were chosen in different forest types of the Langbian Plateau and neighboring areas, including cloud forest, evergreen forest, mixed forest of hardwoods and bamboo, and cultivated area in buffer zone, at elevations from 200 m to around 2000 m. Survey sites are located both within protected areas and in buffer zones of Chu Yang Sin National Park, Bidoup - Nui Ba, and Phuoc Binh national parks, Ta Dung Nature Reserve, and Song Luy and Song Mao watershed forests (Figures 3 & 4).

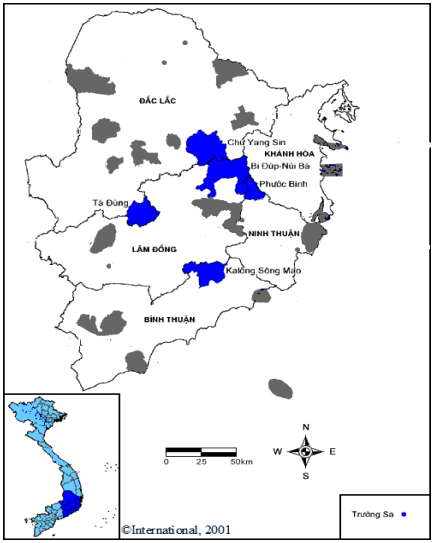

Figure 3. Locations of protected forests in south central, Vietnam. Selected sites for surveys are marked with blue.

(Modified after Birdlife. 2001a)

Chu Yang Sin National Park (CYS NP) is situated at $12^{0}14'16"-12^{0}30'58"$N, $108^{0}17'47"-108^{0}34'48''$E, in the northern margin of the Langbian Plateau, in Krong Bong and Lak districts, Dak Lak Province.

Topography of the Park is mountainous with elevations 600−2440 m and dominated by Chu Yang Sin Peak, at 2442 m. Main streams in the forest are Ea K'Tuar and Ea Krong Kmar, which joint to Ea Krong Ana River in the North and streams in the South of the forest

drain into the Krong No River. Both the Ea Krong Ana and Krong No rivers flow west and north before joining Serepok River (Birdlife, 2010). Dominant vegetation is broad leaves evergreen forest that spreads over 38000 ha (or 65% of the area of the Park). Lowland semi-evergreen forests characterized by members of Dipterocarpaceae, present at elevations below 900 m, with canopies exceeding to 30 m in height. Montane evergreen forests, at above 900 m, are dominated by Fagaceae, Lauraceae, Meliaceae, and Iliciaceae with multiplayer canopies, about 20−30 m in height. Coniferous forests, dominated by *Pinus kesiya*, also grow at elevations above 900 m, in pure stands on well drained exposed ridges. Mossy forest or cloud forest occurs on top of the mount Chu Yang Sin, with *Lyonia* and *Bamboo arundinaris* (Birdlife, 2010).

Bidoup - Nui Ba National Park (BDNB NP) is located at $12^0$00'04"−$12^0$52'00" N, $108^0$17'00"−$108^0$42'00"E, in Lac Duong District, Lam Dong Province and borders the Chu Yang Sin National Park, Dak Lak Province in the Southeast. Natural feature of Bidoup - Nui Ba National Park is mountainous, at elevations from 800 m to above 2000 m, the highest peak (Bidoup) reaching to 2287 m, in southeastern part of the Park. Others mounts around 2000 m are Gia Rich (1923 m), located at eastern margin, next to Phuoc Binh National Park, Ninh Thuan Province; Hon Giao (2062 m), located at northeastern margin; Langbian (2167 m) in the West; Chu Yen Du (2053 m) at western edge of the Park (Birdlife, 2001a; Nguyen & Kuznetsov, 2012). The Park with an area of 64800 ha, primarily consists of the following vegetation: (1) evergreen forests mixed with bamboo forests, at elevations between 800−1200 m, along Krong-No River, at the northwestern margin. (2) Evergreen forests at elevations between 1500−1800 m, with closed multilayer canopies, reaching near to 25 m, shrub layer covering about 10−12%. Evergreen forests at elevations above 1800 m, with closed multilayer canopies, up to 35 m in height, well developed shrubs, about 20−40%; an annual rainfall 2300−3000 mm; a relative humidity of 89−95%. (3) Evergreen forests and coniferous forests, covering about 14308 ha, are present at elevations above 1700 m. (4) Cloud forests with plenty of mosses covering ground and trunks, closed canopies under 20 m, grew on the tops of Bidoup, Chu Yen

Du, Gia Rich & Hon Giao (Birdlife, 2001a, 2001b; Nguyen & Kuznetsov, 2012).

Phuoc Binh National Park (PB NP), with an area of 19800 ha, is located at $11^0$58'32''–$12^0$10'00'N, $108^0$41'00''–$108^0$49'05''E, on eastern border of the Langbian Plateau and contiguous with the Bidoup - Nui Ba National Park at its western boundary. Topography of this Park is mountainous, at elevation range of 200−1800 m, with high peaks (Gia Rich and Hon Chang Mounts at 1926 m & 1978 m, respectively) in the West and the Northwest of the Park, sloping down in the Southeast, towards the coastal lowlands. The natural vegetation of this area comprises evergreen forests and coniferous forests (Birdlife, 2001a).

Ta Dung Nature Reserve (TD NR), an area of 22100 ha, situated within the Langbian Plateau, in Dak Glong District, Dak Nong Province, at $11^0$47'27"–$11^0$59'20" N, $107^0$53'10"–$108^0$6'32" E, has elevations from 600 to 1982 m at the highest mountain, Mount Ta Dung. Streams in the forest flow into Dong Nai and Krong No rivers. The Ta Dung Natural Nature Reserve is covered by predominantly evergreen forests at elevations above 800 m and secondary forests at elevations below 800 m (Birdlife, 2001a; Hoang et al., 2010). Forests at elevations between 400−1000 m are dominated by Fabaceae, Meliaceae, with multilayer canopies, reaching 40−50 m in height. Forests at elevations between 1000−1600 m are dominated by members of Fagaceae, canopies are provided by plants of Magnoliaceae with 40−50 m in height. Coniferous forests are also present at this range of elevations, with canopies being 20−30 m in height. Mossy forest occurs on top of the Ta Dung Mountain (1982 m).

Song Luy and Song Mao watershed forests (SLSM) are an extension area of the Langbian Plateau, in Binh Thuan Province, with an approximate area of 20000 ha. This is a transition region between the highland and coastal lowland, located at around 11°20'−11°32'N and 108°16'−108°34'E (Le & Tran, 2000). Streams within the watershed are drained by Luy and Mao rivers. The area is dominated by semi-evergreen forests and deciduous forests at elevations between 200−500 m, canopies of the forest are provided

mainly by the genera *Lagerstroemia*, *Cratoxylon*, and *Peltophorum*. The deciduous forests with dominant species of the genus *Dipterocarpus* developed from the semi-evergreen forests as consequence of exploitation or shifting cultivations; evergreen forests occur at elevations above 500 m up to 1100 m, with dominant species represented by Dipterocarpaceae, Fabaceae, Fagaceae, and Sapindaceae that provide closed canopy, about 25−30 m in height, with secondary vegetation with bamboo forest, grassland, shrubs and shrubs with scattered trees (Le & Tran, 2000; Birdlife, 2001a).

1.2. Survey efforts

A total of 15 field surveys were performed within three years (2010−2012) in the Langbian Plateau. Periods of time and locations of each survey are listed in Table 2 and Figure 4. The surveys were conducted at the most active time of frogs, between 18:00−24:00 h but few species (e.g., toads, microhylids) were also recorded during the day.

Table 2. Survey efforts in the Langbian Plateau, Vietnam.

Duration of time	Survey site	Forest
18−30/03/2010	01,03−06	BDNB NP
26−30/04/2010	02−04	BDNB NP
07−20/06/2010	07−08, 11−14	BDNB NP
12−20/07/2010	04, 28, 30, 32	TD NR
20−25/12/2010	31, 34, 35	TD NR
07−11/03/2011	29, 31	TD NR
14−20/04/2011	29	TD NR
27/05−06/06/2011	15−19	CYS NP
20−28/06/2011	03−05	BDNB NP
13−20/07/2011	33−34	TD NR
01−08/08/2011	03, 09, 10	BDNB NP
03−28/08/2011	36−38	SLSM
22−30/09/2011	23, 25, 26, 27	PB NP
12−17/10/2011	20−21	CYS NP
14−20/08/2012	22, 24	PB NP

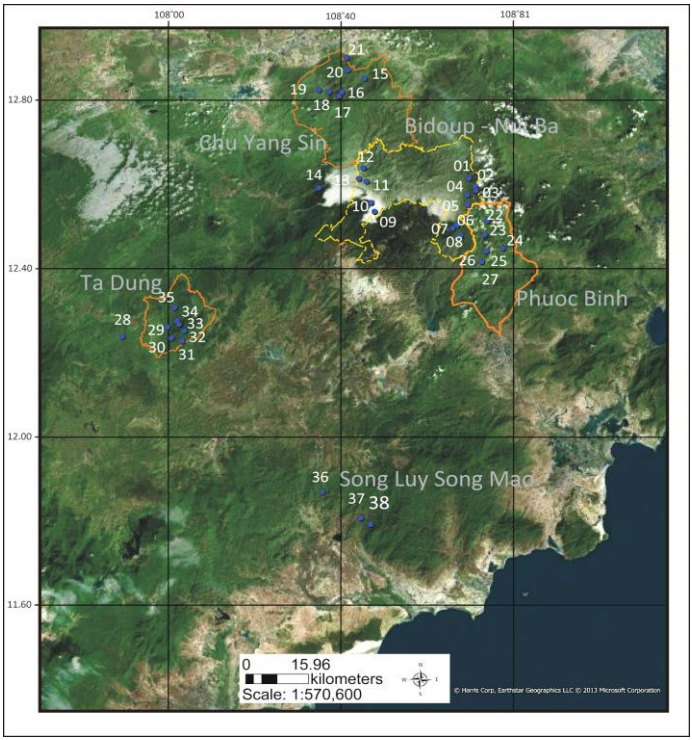

Figure 4. Survey sites (blue circles) in the Langbian Plateau, Vietnam.

1.3. Sampling

Existences of amphibian species in the survey sites were recorded by using of digital cameras and through voucher specimens collected during the surveys. Specimens were collected by hand in the field. After taking photographs, the specimens were anesthetized by 10% ethanol, then, fixed in 80% ethanol and finally stored in 70% ethanol. The preserved specimens were subsequently deposited in the museum collections of The University of Science, Ho Chi Minh City, Vietnam (US) and The Zoological Research Museum Alexander Koenig (ZFMK), Bonn, Germany.

Tissue samples (pieces of muscle or liver) were collected and preserved in 95% ethanol for subsequent molecular analyses.

1.4. Call recording

Advertisement calls of the anurans from the study sites were recorded by Edirol R-09 HR recorder or Zoom H4n Handy Mobile 4-Track recorder in combination with Rode NTG-2 condenser shotgun microphone, with a distance between 0.2−0.5 m away from the focal calling frog, during the surveys. Numbers of the recordings that were conducted for each individual were different depending on the number of calls per time and how frequently the calling male performed calls. The calling males were subsequently collected for morphological examinations.

Coordinates and elevations of the survey sites were taken by a Garmin GPSMAP®60Cx. Information of activities and environmental conditions where the specimens and/or recordings were collected (e.g., humidity, temperature, time, location, microhabitat and current status of the frogs) were recorded by direct observations and by using Kestrel 4000 Pocket Weather Meter or Reed LM-8000 Anemometer.

2. Analyses

2.1. Morphological analyses

A total of 651 specimens were examined and identified to the species level. Nomenclature followed Frost (2013). Common names followed Frost (2013) and Nguyen et al. (2009). Morphological features of each specimen were examined by using Olympus stereo microscope and digital caliper 0−200 mm, accurate to the nearest 0.1 mm. The features were compared with the original and previous descriptions. Measurement parameters were used as follows:

Head and body. (1) Snout vent length (SVL): distance between tip of snout to vent; (2) Head length (HL): distance between tip of snout to posterior edge of mandible; (3) Head width (HW): the greatest distance of the head; (3) Snout length (SNL): distance between tip of snout to anterior corner of eye; (4) Internarial

distance (IN): distance between nostrils; (5) Eye diameter or eye length (ED): the widest horizontal diameter of eye; (6) Interorbital distance (IO): the smallest distance between internal edges of eyes; (7) Upper eyelid's width (UEW): the greatest distance between internal edge of eye and external margin of upper eyelid; (8) Tympanum diameter or tympanum length (TD): the greatest horizontal diameter of tympanum; (9) Eye-tympanum distance (E-T): the smallest distance between posterior corner of eye and posterior edge of tympanum.

Limbs: (10) Length of upper arm (UAL): distance between level of insertion of forearm into body and elbow; (11) Length of lower arm (LAL): distance between elbow and base of inner palmar tubercle; (12) Length of hand (HAL): distance between base of inner palmar tubercle and tip of the longest finger; (13) Length of finger: distance between tip of finger and proximal margin of proximal subarticular tubercle (or of swollen callous bump at position corresponding to the subarticular tubercle, in case subarticular tubercles on fingers were replaced by callous bumps); (14) Length of inner metacarpal tubercle (IMCL): distance between base and distal edge of the inner metacarpal tubercle; (15) Length of nuptial pad: distance between the internal and external edges of the pad; (16) Length of thigh (THL): distance between vent and knee; (17) Length of tibia (TBL): distance between knee and base of tarsus; (18) Length of foot (TFOL): distance between base of tarsus and tip of the longest toe; (19) Length of toe: distance between tip of toe and proximal margin of proximal subarticular tubercle on the toe; (20) Length of inner metatarsal tubercle (21) Length of inner metatarsal tubercle (IML): distance between base and distal edge of the inner metatarsal tubercle; (22) Width of disc: the largest horizontal width of discs on the third finger or the fourth toe.

Webbing between fingers or toes. Formula of webbing followed Guayasamin et al. (2006) (Figure 5). Roman numerals represent fingers or toes. Arabic numerals represent the number of phalanges completely or partially free of webbing as follows: 0 indicates that the web reaches to disc; 1 indicates that the web reaches to the intercalary cartilage; 2 indicates that the web reaches to the distal subarticular tubercle; the notation for 3 and 4 follow the same pattern described for 2. In case of the web reaching a level between the structures (disc, intercalary, or subarticular tubercles), an appropriate notation is with fractions (e.g., ⅓ when the distal one-third of the phalanx is free).

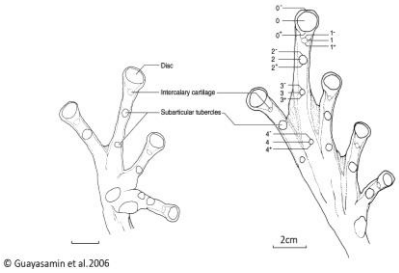

Figure 5. Formula of webbing following Guayasamin et al. (2006).

Color pattern and skin texture. Photographs achieved from the field surveys, combined with observation directly from the specimen under Olympus stereo microscope were performed for color patterns and skin textures assessment.

2.2. Acoustic analyses

Sound, in phonetic aspect, is mainly distinguished based on three factors: loudness, pitch, and quality (Ladefoged, 1962). Loudness of a sound is estimated via its intensity. The louder sound has higher amplitude and higher intensities (Ladefoged, 1962; Wagh & Deshpande, 2013). Difference in pitch of a sound is related to its frequency, a rate at which cycles of sound wave occur and is usually measured in Hertz (Hz) (Ladefoged, 1962; Wagh & Deshpande, 2013). Variation of sound is also considered in quality, indicated by shape of the sound wave (Ladefoged, 1962). In a complex wave, it may be composed of more than one frequency. The lowest frequency in the harmonic spectrum is fundamental frequency or

the first harmonic. The second harmonic, also called as the first overtone, is the frequency twice the first harmonic. And the harmonic n^{th} is the frequency with n times multiple the fundamental frequency (Ladefoged, 1962; Duellman & Trueb, 1994).

In order to figure out characters of anuran calls, the sounds were analyzed by using Raven Pro, version 1.3 (Cornell Laboratory of Ornithology, Ithaca, New York, U.S.A.) at resolution of 16 bit and frequency of 44.1 kHz. Spectrograms were performed with Hann window type, frame length of 1024 samples, and corresponding 3 dB filter bandwidth of 67.4 Hz; frame overlapped 50 % with time-grid resolution of 512 samples and frequency-grid resolution of 46.9 Hz. For each acoustic signal, the following parameters were measured (Figure 6): (1) Call duration or call length (s): duration of time between beginning and end of a call; (2) Call repetition rate (calls/s): (total number of calls−1)/ duration of time between beginning of the first call and end of the last call; (3) Inter-call interval (s): duration of time between end of the first call and beginning of the second call; (4) Number of notes per call: total number of notes in a call; (5) Note duration or note length (s): duration of time between beginning and termination of a note; (6) Inter-note interval (s): duration of time between end of the first note and beginning of the second note (7) Note repetition rate (notes/s): (total number of notes in a call−1)/ call duration; (8) Number of pulses per note: total number of pulses within a note (in some cases); (9) Dominant frequency of call (kHz): the emphasized harmonic in the spectrum; (10) Fundamental frequency of call (kHz): the lowest harmonic in the frequency spectrum; (11) Average intensity (dB): average power of a call (used only for comparing calls in chorus). (Terms and methods after Duellman & Trueb, 1994; Cocroft & Ryan, 1995).

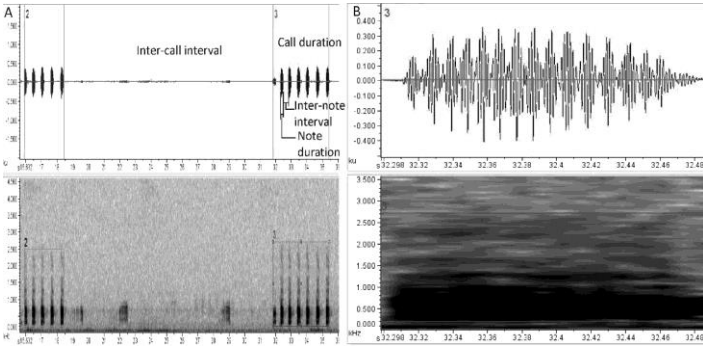

Figure 6. Oscillogram (above) and spectrogram (below) of acoustic signals of *Brachytarsophrys intermedia*.

The oscillogram show: (A) two calls with five and seven pulsed notes for each & (B) magnitude of the second note within the call 3. This note is composed of 15 pulses. The spectrograms show a fundamental frequency of 0.3 kHz plus other harmonics, and the dominant frequency of 0.6 kHz is associated with the second harmonic.

2.3. Statistical analyses

Species richness and dissimilarity of species composition among populations within the study area were analyzed by using Biodiversity, vegan, and ecodist packages in R version 2.15.1 (Kindt & Coe, 2005).

For bioacoustics, descriptive statistics were presented as mean ± SD (range of min−max). ANOVAs and Turkey-tests were used for comparing acoustic characteristics of individuals among populations. T-tests were conducted in case of comparing calls of individuals between two populations or two periods of calls in chorus. Pearson correlations were used for examining the relationship between SVL of the calling males and their vocal properties (for species that have data enough for statistical analysis). Data for estimate effects of temperature and relative humidity on the vocal properties was not enough for statistical analyses except for that from calls of species *Leptolalax bidoupensis.* The effects were calculated by using Multivariate Analysis of Variance (MANOVA). All the statistical tests were used an alpha level of 0.05 with program R version 2.15.1

CHAPTER III. RESULTS

1. Species diversity

In this study, we recorded a total of 44 species belonging to 23 genera, 6 families of amphibians from the Langbian Plateau. The most diverse family was Rhacophoridae (16 species), followed by Microhylidae (8 species), Ranidae (7 species), Megophryidae (6 species), Dicroglossidae (5 species), and Bufonidae (2 species).

Geographically, 30 species were recorded from BDNB NP, 18 from CYS NP, 20 from PB NP, 25 from TD NR, and 18 from SLSM. The curves for the separate forests showed that the species richness of the forests of BDNB NP nearly reaches the limit. Slopes of the species accumulation curves for the forests of SLSM and CYS NP become to descrease, whereas those for the forests PB NP and TD NR are still steep. The species accumulation curve for the whole survey sites nearly approaches the horizon (Figure 7).

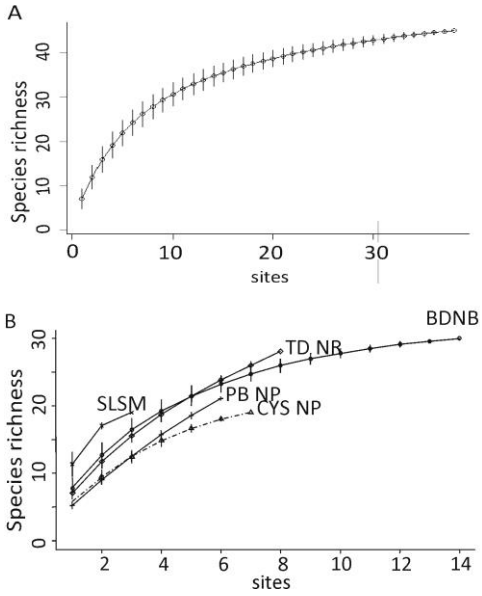

Figure 7. (A) Species accumulation curve of amphibian assemblage for the whole survey sites in the Langbian Plateau. (B) Species accumulation curves for various forests of BDNB NP, CYS NP, PB NP, TD NR, & SLSM within the Langbian Plateau.

Remarkably, three new species have been recently described from the Langbian Plateau by our working group, comprising two species of Megophryidae (*Leptobrachium leucops*, *Leptolalax bidoupensis*), one species of Rhacophoridae (*Rhacophorus vampyrus*).

Taxonomic accounts were provided in detail as below.

Bufonidae

Duttaphrynus melanostictus (Schneider, 1799)

English name: Asian Black-spotted Toad

Vietnamese name: Coc Nha

(Plate 1. A)

Because this is a widespread species, no animal was collected for voucher specimen. However, photographs of a toad were taken near 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 19 July 2010.

Diagnosis. Size medium; strong canthal, supraorbital, postorbital, preorbital, and supratympanic crests; parotoids large, much longer than wide; skin with numerous warts that bear spines (after Taylor, 1962).

Morphological characters. Head large with well-developed ridges in canthus rostralis, supraorbital, and postorbital regions; paratoid gland large, long, commencing from supratympanic region to axilla; tympanum distinct; skin very rough with numerous large warts that bear black spines; dark grey above and whitish below (identification followed Taylor, 1962).

Distribution. This species has a wide distribution in Asia with elevations up to 2000m (Taylor, 1962).

***Ingerophrynus galeatus* (Günther, 1864)**

English name: Gamboja Toad, Bony-headed Toad, Cambodia Toad

Vietnamese name: Coc Rung

(Plate 1. B)

Examined specimens. DT0276 (male) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0649 (male) was collected at 12°252838 N, 108°441305 E, alt. 641 m, in BDNB NP, on 15 June 2010; DT0532−33 (males) were collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 05 June 2011; DT0884 (male) was collected at 11°90753 N, 108°016004 E, alt. 967 m, in TD NR, on 22 December 2010. Photographs were taken near to 12°046768 N, 108°776413 E, alt. 393 m, from PB NP on 19 August 2012.

Diagnosis. Dorsal skin with warts and tubercles; a pair of large parotoid glands with a bony ridge connecting posterior region of eyes and the parotoid glands.

Morphological characters. SVL 44.8—56.0 mm in males (n = 4), 64.8 mm in female (n = 1); head broader than long, ratio HL/SVL 0.30—0.35; snout truncate in dorsal view; nostril round, very close to tip of snout; eye large, ED/SNL 0.98, IO/UEW 0.97; tympanum very distinct, surrounded by elevated rim, TD/ED 0.30—0.58 times that of eye; E-T/TD 0.48—1.19; supratympanic fold absent; parotoid glands large, elongated, protruding; bony ridge long, thick, raised, connecting posterior corner of eye and parotoid gland; vomerine teeth absent; choanae round, partly hidden under upper jaw; tongue round, free behind for 0.28—0.46 times of its length.

Fore limbs short; relative finger length: II < IV < I < III; tips of fingers round; fingers free of webbing; subarticular tubercles on fingers round and swollen; inner metacarpal tubercle long and prominent, its length being 0.50—0.70 times of the first finger length; outer metacarpal tubercle pronounced and much larger than the inner tubercle; tibiotarsal articulation touching tympanum or eye; heels not in contact when legs are folded at right angles to body; relative

toe length: I < II < V < III < IV; tips and subarticular tubercles on toes similar to those on fingers; toes webbed, formula: I1½−2½II1¼−2.¾III2½−3½IV3−1½V; inner metatarsal tubercle elongated, conspicuous, its length 0.53—1.26 times of the first toe length; outer metatarsal tubercle distinct, ovoid, smaller than the inner metatarsal tubercle; tarsal fold absent.

Dorsal skin very rough with warts and tubercles; skin on ventral surface coarsely granular; an oblique row of large and pointed tubercles, running from rear of rictus to above level of axilla; tubercles on upper part of flank round and flattened; a series of glandules arranging in line, extending from behind parotoid gland to groin; skin on lower part of flank coarsely granular.

Coloration in life. Dorsal surface of body ground yellow to reddish grey; head with a light yellow bar between orbits; posterior part of head with dark brown or black mark, in irregular shape; lateral head yellow to reddish grey; undersides of canthus rostralis, upper eyelid, parotoid gland with small, dark brown spots; upper lip with thick, dark brown bars; tympanum dark brown; dorsal surface of limbs yellowish brown, with dark cross-bars (identification followed Boulenger, 1920; Smith, 1921; Inger et al., 1999; and Stuart et al., 2006).

Sexual dimorphism. Nuptial pad present in males, dark brown, covering dorsal and lateral surfaces of the first finger, 1—1.5 times in length of the first finger.

Distribution. *I. galeatus* has a wide distribution in Indochina and adjacent areas, including China, Cambodia, Laos, and Vietnam at elevations between 100—1300 m (Inger et al., 1999; Stuart et al., 2006; Hendrix et al., 2009; Frost, 2013). This species has been reported from Lao Cai, Thai Nguyen, Vinh Phuc, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Thua Thien Hue, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Dak Lak, Lam Dong, Dong Nai provinces of Vietnam (Nguyen et al., 2009). This species was encountered at elevations up to 1500 m in the Langbian Plateau. This is the first record of *I. galeatus* from Dak Nong Province.

Megophryidae

Brachytarsophrys intermedia (Smith, 1921)

English name: Annam Spadefoot Toad

Vietnamese name: Coc Nui Got

(Plate 1. C—F)

Examined specimens. DT0169 (male) was collected at 11°75544 N, 108°700715 E, alt. 1515 m, on 19 March 2010; DT0253 (female) was collected at 12°212795 N, 108°699444 E, alt. 1399 m, on 28 March 2010; DT0261—263 (males) were collected at 12°179743 N, 108°695955 E, alt. 1484 m, on 30 March 2010; all specimens were collected from BDNB NP. Photographs of a female were taken at 12°079296 N, 108°734607 E, alt. 782 m, in PB NP, on 29 September 2011 and those of males were taken at 12°461853 N, 108°417369 E, alt. 1042 m, in CYS NP, on 16 October 2011.

Diagnosis. Size very large, SVL up to 100 mm; upper eyelid with a dermal, leaf-shape projection; a pair of dermal hems, continue or broken, commencing from shoulder to middle of dorsum, nearly parallel with the supratympanic fold; dermal tubercles being on dorsum and flank.

Morphological characters. The specimens agree with descriptions of *Brachytarsophrys intermedia* by Smith (1921) and Bourret (1942) by having: size very large, SVL 58.1—104.5 mm (males 98.0—104.5 mm, n = 4; female 58.1 mm, n = 1); head round, broader than long; snout round in dorsal view, truncate and protruding lower jaw in profile; snout very short, its length 0.12—0.14 times of head length; nostril with flip of skin, midway between tip of snout and eye; canthus rostralis very sharp; loreal region concave; eye large, ED/SNL 0.75—0.95; IO/UEW 1.26—1; upper eyelid with tubercles and a long, pointed dermal protruding, forming a leaf shape projection upon the eye; tympanum covered by skin; supratympanic fold distinct, extending from posterior of eye to above level of insertion of

forearm into body; vomerine teeth present, in two rows; tongue nick at rear.

Limbs short and robust; tips of fingers blunt and swollen; fingers short, without webbings; callous bumps on fingers low; inner metacarpal tubercle flat; hind limbs short, with tibiotarsal articulation nearly touching tympanum; relative toe length: I < II < V < III < IV; tips of toes blunt and swollen; webbing formula: $I_{1-2½}II_{2-3}III_{2¼-3½}IV_{4-2}V$; callous bumps on toes similar to those on fingers; inner metatarsal tubercle oval and flat, its length more or less equal to the first toe length; outer metatarsal tubercle and tarsal fold absent.

Skin on dorsum with a pair of noticeable, oblique dermal hems, commencing from shoulder to middle of dorsum, nearly parallel with the supratympanic fold; upper part of flank tubercular; chin and throat smooth with tiny granules; belly smooth.

Coloration in life. Dorsal surfaces of head and anterior part of dorsum bronze or dark brown; posterior part of dorsum with flecks or reticulations with dark brown; dorsolateral region lighter; dark bars below eye; a dark brown patch on tympanal region; transverse dark brown cross-bars on limbs present. Young individuals are yellowish with more distinguished markings.

Sexual dimorphism. Males reddish brown to dark brown; females yellow to dark bronze, dermal hems and projections on dorsum more developed in females than in males.

Taxonomic remarks. The examined specimens do not match previous descriptions in the following characters: interorbital distance about 1.26—1.47 of the upper eyelid's width (versus the ratio of IO/UEW = 1.5—2.0 in Smith's description, 1921); tympanum vertical oval, 0.28—0.49 times of eye diameter, Eye-tympanum distance 2.37—3.58 times of eye diameter; choanae horizontal oval, partly concealed by edge of lower jaw; tongue free posteriorly for 0.32—0.46 times of its length; inner metacarpal tubercle oval, longer than the first finger; heels far away from each other when legs are folded at right angles to body (not mentioned by Smith, 1921 and Bourret, 1942).

Extending description of skin texture and coloration patterns

Dorsal surface of body and limbs smooth with tiny granules, more dense around vent region; a light fold crosses posterior part of head, at level of tympanum; a pair of dermal hems, continuous or interrupted, from shoulder to middle of dorsum; some small, long or round, dermal projections, in posterior part of dorsum; end of supratympanic fold with elongated and pointed dermal projections; one or two small dermal projections present in the region between end of supratympanic fold and angle of mandible; upper part of flank glandular and granular, with some dermal projections in anterior region, arranged in a row of dermal projections or forming a dermal hem; lower part of flank granular; ventral surfaces of body and limbs smooth; chin, throat and thigh with tiny granules; axillary gland present on chest; femoral glands prominent on posterior surface of thigh, a little closer to knee than to vent.

Coloration in life. Dorsal and lateral surfaces of body and limbs reddish brown to dark brown; a thin, blurry dark brown cross-bar in interorbital region; posterior part of dorsum with dark brown reticulation; base of dermal projections on dorsum dark brown or black; a thick, lighter brown stripe running from shoulder to rump; side of head lighter; ventral margins of upper eyelid and supratympanic fold dark brown; a thin, dark brown stripe from canthus downward to near angle of mandible; an oblique light brown to light bronze stripe extending from rear of eye to beyond angle of mandible; another dark brown stripe edged below posterior part of supratympanic fold, partly covers the tympanum; folds on dorsum and flank edged by long, thick, dark brown markings; tubercles on flank light brown to yellow; tops of granules on flanks and limbs white; alternating dark brown and reddish cross-bars on limbs thick; chin and throat brown with some dark brown flecks; margin of lower jaw yellow; a large, “U-shape”, irregular margin, light brown mark being on throat, from below level of midway between eye and tympanum to just in front of axillary gland; some irregular shaped and sized, dark brown flecks inside the “U-shape” mark; all marks and flecks on chin and throat bordered with thin, light brown outlines; chest and belly reddish brown, marbled with dark brown;

ventral surfaces of thigh and tibia grey, staining to whitish grey at outer part; callous bumps, tips of fingers and toes flesh grey; axillary gland white; femoral white or dark brown; iris reddish or brown; pupil vertical oval and black.

Distribution. *B. intermedia* was common in the Langbian and Kon Tum plateaus, at elevations from 900 to above 1500 m (Smith, 1921, Frost, 2013). Existences of this species, in Vietnam, have been reported from Thua Quang Binh, Kon Tum, Gia Lai, Dak Lak, Lam Dong, Dong Nai (Nguyen et al., 2009). This is a new provincial record of this species from Ninh Thuan Province.

***Leptobrachium leucops* Stuart, Rowley, Tran, Le, and Hoang, 2011**

English name: White-eye Spacefoot Toad

Vietnamese name: Coc May Mat Trang

(Plate 1. G—I)

Examined specimens. DT0066 (male) was collected at 12°0939 N, 108°66 E, alt. 2108 m, in BDNB NP, on 20 March 2010; DT0083 (female) was collected at 12°094939 N, 108°660495 E, alt. 2027 m, in BDNB NP, on 21March 2010; DT0320—22 (females) were collected at 12°194821 N, 108°712284 E, alt. 1908 m, in BDNB NP, on 26 April 2010; DT0343—45 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 27 April 2010; DT0359—61 (females) were collected at 12°196619 N, 108°712594 E, alt. 1942 m, in BDNB NP, on 27 April 2010; DT0405 (male) was collected at 12°101601 N, 108°66933 E, alt. 1781 m, in BDNB NP, on 10 June 2010; DT0451 (male) was collected at 11°856131 N, 108°037052 E, alt. 1932 m, in PB NP, on 25 September 2011; DT0453—54 (males) were collected at 12°041274 N, 108°738492 E, alt. 1166 m, in PB NP, on 27 September 2011; DT0922 (male) was collected at 120037657 N, 108°735716 E, alt. 1065 m, in PB NP, on 28 September 2011; DT0762 (male) was collected at 11°850156 N, 108°018092 E, alt. 1711 m, in TD NR, on 17 July 2010; DT0866—67 (males) were collected at 11°874521 N, 108°020219 E, alt. 1309 m, in

TD NR, on 23 December 2010; DT0961—62 (males) & DT0963 (female) were collected at 11°856131 N, 108°037052 E, alt. 1932 m, in TD NR, on 27 July 2011.

Diagnosis. Skin with network of ridges; underside dark grey with tiny white spots on tubercles; iris white dorsally, blue scleral arc (after Stuart et al., 2011).

Morphological characters. SVL 40.5—53.0 mm in males (n = 10), 36.1—50.2 mm in females (n = 12); head depressed, as long as wide; snout round in dorsal view, sloping or truncated in profile; SNL/HL 0.5; nostril round, closer to tip of snout than eye; canthus rostralis distinct; loreal region oblique and concave; eye large and raised, ED/SNL 0.69—0.98; IO/UEW 0.79—1.39; tympanum visible, round, TD/ED 0.34—0.63, E-T/TD 0.44—1.11; supratympanic fold distinct; vomerine teeth absent; choanae round, hidden under the lower jaw edge; tongue notched and free behind.

Fore limbs slender; relative finger length: II < = IV < I < III; tips of fingers and toes round and swollen; webbing between fingers absent; callous bumps present on fingers; two metacarpal tubercles oval and prominent, the inner larger than the outer; tibiotarsal articulation reaching to tympanum; relative toe length: I < II < III < V < IV; toes webbed, formula: $I_{2-2}II_{2-3}III_{2½-3½}IV_{4-2}V$; callous bump on toes smaller than those on fingers; inner metatarsal tubercle conspicuous, its length 0.67—1.30 times of the first toe length; outer metatarsal tubercle and tarsal fold absent.

Skin smooth dorsally, with network of fine ridges which are longer and more obvious than those on the body; side of head covered with tiny granules; upper part of flank similar to dorsum, lower part of flank with minute granules; venter finely granular; skin on ventral surfaces of limbs and behind surface of thigh smooth except for inner part of ventral surface of thigh finely granular; skin surrounding vent region warty; axillary gland large, round, being on ventrolateral and posterior insertion of forearm to body; femoral gland swollen, being on posteroventral surface of thigh, its location closer to knee than vent.

Coloration in life. Back light or dark grey with few small, reddish dots; some larger white spots, irregular in shape and size, on dorsum; side of head light or dark grey; edges of the canthus rostralis and upper eyelid dark grey or reddish; a dark brown stripe under the canthus rostralis, from rear of nostril to canthus, through upper eyelid, to end of supratympanic fold; this stripe enlarging and masking the tympanum region; dark grey cross-bars on upper lip present; upper part of flank resembling dorsum, with more dense white spots, lower part of flanks dark brown with small, white spots; chin grey or brown with blurry whitish marbling; throat and chest brown or grey; belly dark brown, with tiny white dots; dorsal surface of limbs light grey or dark grey, with transverse cross-bars, the dark grey bars thinner than the white bars; ridges on limbs, sometimes reddish or orange; posterior surface of thigh dark brown, with tiny white dots; tips of fingers and toes, callous bumps, metacarpal tubercles, and inner metatarsal tubercle white; axillary gland and femoral gland white; iris dorsally white, ventrally dark brown or grey; scleral arc blue; pupil black, vertical and partly immersing into the white part of iris like a spine (after Stuart et al., 2011).

Taxonomic remarks. The specimens disagree with the original description (Stuart et al., 2011) as follows: tympanum 0.33−0.59 times of eye diameter (versus the TD/ED 0.4); supratympanic fold very distinct (versus the low supratympanic ridge); two metacarpal tubercles separated from each other (versus the two metacarpal tubercles in contact); and femoral gland elongated (versus the femoral gland round).

Distribution. This recently discovered species has been known from the type locality of Langbian Plateau, in Lam Dong and Khanh Hoa provinces, Vietnam, at elevations between 1558−1900 m (Stuart et al., 2012). Distribution of the species is extended towards the East, in Ninh Thuan Province, and the South, in Dak Nong Province, at elevations of 931−2108 m. Occurrences of this species are restricted to the evergreen forests and cloud forests.

Reproductive biology (Plate 12). A pair of this species was encountered in amplexus on the ground, about 2 m, away from a small stream. This species has an inguinal amplexus pattern.

Tadpoles and metamorphs of this species were found in small, rocky streams, in montane evergreen forests, at elevations above 1500 m.

***Leptobrachium pullum* (Smith, 1921)**

English name: Vietnam Spadefoot Toad

Vietnamese name: Coc May Viet Nam

(Plate 2. A—C)

Examined specimens. DT0035—36 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0162 (male) was collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 19 March 2010; DT0238—39 (males) were collected at 12°212795 N, 108° 699444 E, alt. 1399 m, in BDNB NP, on 28 March 2010; DT0274 (male) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0281 (male) was collected at 12°179743 N, 108°695955 E, alt. 1484 m, in BDNB NP, on 21 April 2010; DT0305—06 (males) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 24 April 2010; DT0338 (male) & DT0346 (female) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 27 April 2010; DT0362 (female) was collected at 12°196619 N, 108°712594 E, alt. 1942 m, in BDNB NP, on 27 April 2010; DT0906, DT0909 (males), DT0905, DT0907—08 (females) were collected at 12°418102 N, 108°371515 E, alt. 999 m, in CYS NP, on 27 May 2011; DT0803, DT0806, DT0809 (males) were collected at 12°417312 N, 108°375496 E, alt. 1133 m, in CYS NP, on 28 May 2011; DT0978 (female) was collected at 12°471149 N, 108°416678 E, alt. 1030 m, in CYS NP, on 15 October 2011; AMNH17566 (male) was collected near to 11°49416 N, 108°53942 E, alt. 791 m, in SLSM, on 05 August 2011; AMNH17574, AMNH17589 (males), AMNH17575 (female) were collected near to 11°4984 N, 108°361 E, alt. 751 m, in SLSM, on 06 August 2011; AMNH16847, AMNH16848 (males) were collected at 11°4852 N, 108°3640 E, alt. 541 m, in SLSM, on 12 August 2011; DT0684, DT0687—91; DT0694, DT0697—08 (males) were collected at

11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13 July 2010; DT0779 (female) was collected at 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 18 July 2010; DT0837 (male) was collected at 11°907119 N, 108°015497 E, alt. 997 m, in TD NR, on 21 December 2010; DT0863—65 (males) were collected at 11°90753 N, 108°016004 E, alt. 967 m, in TD NR, on 22 December2010; DT0473, DT0482 (females) were collected at 11°828251 N, 108°033999 E, alt. 1425 m, in TD NR, on 08 March 2011; DT0959 (male) was collected at 11°856131 N, 108°037052 E, alt. 1932 m, in TD NR, on 25 July 2011. Photographs taken from surveys near to 11°4984 N, 108°3610 E, alt. 541, in SLSM, in August 2011.

Diagnosis. Head large and depressed; skin with fine network of ridges dorsally; ventral surface whitish except brownish chin; iris orange-red dorsally and dark brown or black ventrally; scleral arc yellowish orange.

Morphological characters. SVL 40.6—53.5 mm in males (n = 32), 38.4—69.2 mm in females (n = 13); head large and depressed, as long as broad; snout round in dorsal view, truncated and proceeding to lower jaw in profile; nostril round, midway between tip of snout and eye; canthus rostralis distinct; loreal region oblique and concave; ED/SNL 0.68—0.96; IO/UEW 0.87—1.45; tympanum round, with elevated rim, TD/ED 0.33—0.59, E-T/TD 0.32—1.11; supratympanic fold prominent; vomerine teeth absent; choanae round and completely exposed under lower jaw's ridge; tongue notched and free at rear.

Relative finger length: II < I < IV < III; tips of fingers round and slightly swollen; fingers free of webbing; callous bumps on ventral surfaces of fingers swollen, sometimes, connected; two metacarpal tubercles round, subequal in size; tibiotarsal articulation reaching to tympanum; heels not in contact when legs are folded at right angles to body; relative toe length: I < II < V < III < IV; tips of toes round without disk; webbing between toes: $I_{2-2}II_{2-3}III_{2½-4}IV_{4-2}V$; callous bumps on ventral surface of toes smaller than those on fingers; inner metatarsal tubercle large, elongate and prominent, approximate 0.62—1.43 times in length of the first toe; outer metatarsal tubercle and dermal folds along foot and tarsus absent.

Skin dorsally smooth or with tiny granules, with fine network of ridges; side of head with tiny granules; flank granular; venter coarse granular; ventral surface of limbs smooth; ventral surface of thigh granular; axillary gland round, ventrolateral, just behind position of insertion of forearm to body; femoral gland oval, swollen, smaller than axilla gland, located on posterior surface of thigh, its position at midway between vent and knee or closer to knee than vent.

Coloration in life. Dorsal surface of head and body grey or brown with some pinkish, white and dark brown dots, in irregular shape and size on posterior part of dorsum; dark brown dots sometimes connected together, forming a reticulation; ridges on dorsal surface of body and limbs grey or reddish; lateral head grey with a triangle, dark brown mark in loreal region and a similar mark in anterior canthus region; margin of upper eyelid with or without reddish outline; a dark brown, posterior canthus with an Y-shape stripe, running under the supratympanic fold, enlarged and masking tympanic surface; upper part of flank grey or brown with or without white dots, lower part of flank white; chin brownish, covered by white granules; throat, chest, and belly white; dorsal surface of limbs with transverse cross-bars; ventral side of thigh dark brown, with white spots; iris orange-red dorsally and dark brown or black ventrally; scleral arc yellowish orange; pupil vertical, black, hardly distinguished from the iris (after Ohler et al., 2004 and Stuart et al., 2011).

Sexual dimorphism. Males have internal vocal sac.

Taxonomic remarks. The specimens differ from previous descriptions and reports by having: a larger range of SVL 38.4—69.2 mm in females (n = 45) (versus SVL 44.4—52.8 mm in the report of Ohler et al., 2004) and SVL 42.4−52.4 mm (n = 16) in the description of Stuart et al., 2011); some specimens have a dark grey or dark brown, an Y-shape patch in posterior interorbital region and another V-shape patch present on anterior part of dorsum, at level above tympanum or markings on upper lip (versus dorsum lacking large, dark grey markings and lip bars absent as in the description of Stuart et al., 2011).

Distribution. *L. pullum* has been reported from Kon Tum, Dak Lak, Lam Dong provinces of Vietnam (Nguyen et al., 2009), Laos, Myanmar, Thailand (Frost, 2013). The low elevation limitation of *L. pullum* considered not lower 800 m (Bain & Hurley, 2011), is expanded to 541m by the record from SLSM. In Langbian Plateau, this frog is also the most common species, occurring in four of the five forest types (cloud forest, evergreen forest, mixed forest of large hardwoods and bamboo, and mixed forest of small hardwoods and bamboo), at elevations from 541 to 1932 m. These are the first records of this species from Dak Nong, Ninh Thuan and Binh Thuan provinces, Vietnam.

Reproductive biology (Plate 12). *L. pullum* has a similar pattern of reproduction as *L. leucops*. Five pairs in inguinal amplexus, on the saturate soil or in rocky cracks were accounted on 15 July 2010. They aggregated for breeding near to a rain puddle with about 40 individuals, in an evergreen forest in TD NR. There was rain three days before the survey day. The air temperature and relative humidity at the survey time were 22.3^{o}C & 80.6%, respectively. Another population of more than 30 individuals of this species which gathered for chorus and breeding was encountered in the evergreen forest of CYS NP, on 31 May 2011.

***Leptolalax bidoupensis* Rowley, Le, Tran, and Hoang, 2011**

English name: Bidoup Spacefoot Toad

Vietnamese name: Coc may Bi doup

(Plate 2. D—F)

Examined specimens. DT0291—92, DT0307 (3 males) were collected at 12^{o}186132 N, 108^{o}714042 E, alt. 1553 m, in BDNB NP, on 24 April 2010; DT0334—36 (males) were collected at 12^{o}186132 N, 108^{o}714042 E, alt. 1553 m, in BDNB NP, on 24 April 2010; DT0401 (female) was collected at 12^{o}101872 N, 108^{o}669482 E, alt. 1796 m, in BDNB NP, on 09 June 2010; DT0440—41 (males) were collected at 12^{o}015165 N, 108^{o}727121 E, alt. 900 m, in PB NP, on 24 September

2011; DT0455 (male) & DT0456 (female) were collected at 12°041274 N, 108°738492 E, alt. 1166 m, in PB NP, on 27 September 2011; DT0686, DT0692, DT0696 (males) were collected at 11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13—15 July 2010; DT0770—774 (males) were collected at 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 18 July 2010; DT0950 (male) was collected at 11°856131 N, 108°037052 E, alt. 1932 m, in TD NR, on 24 July 2011; DT0975—76 (males) were collected at 12°155608 N, 108°471208 E, alt. 1932 m, in TD NR, on 27 July 2011. Photographs achieved from surveys near to 11°4883 N, 108°364 E, alt. 577 m, in SLSM, in August 2011.

Diagnosis. Size small; skin smooth; macroglands including supra-axillary, pectoral, femoral, and ventrolateral glands present; iris bicolor (after Rowley et al., 2011b).

Morphological characters. Specimens agree with description of *Leptolalax bidoupensis* (Rowley et al., 2011b) in the following features: body size small, SVL 22.4—28.0 mm in males (n = 23), 17.1—30.2 in females (n = 7); head as long as wide; snout round in dorsal view, round or truncated and protruding lower jaw in profile; nostril round, closer to tip of snout than eye; canthus rostralis distinct, blunt; loreal region oblique and concave; ED/SNL 0.82; IO/UEW 0.93—1.49; tympanum round, TD/ED 0.36—0.61, E-T/TD 0.34—0.72; supratympanic fold present; vomerine teeth absent.

Fore limbs slender; relative finger length: I < II = IV < III; tips of fingers thick, round; fingers free of webbing; two metacarpal tubercles, the inner much larger than the outer; callous bumps on fingers present; tibiotarsal articulation reaching to eye; relative toe length: I < II < V < III < IV; tips of toes and subarticular tubercles on toes similar to those of fingers; toes with poorly developed webbing; inner metatarsal tubercle elongated and pronounced; outer metatarsal tubercle and tarsal fold absent.

Skin with tiny white tubercles dorsally and smooth ventrally; tubercles on head, flanks, and limbs more dense than on dorsum; tubercles on outer upper eyelid more prominent and denser than on surrounding region; supra-axillary gland oval, swollen, being

behind termination of supratympanic fold; axillary gland large, oval, being on chest, at just behind level of insertion of forearm into body; femoral gland oval, located on ventroposterior surface of thigh, its position nearer to knee than vent.

Coloration in life. Back and sides of body and limbs brown with reddish spots on upper arm and elbow; a dark brown mark, in V-shaped in interorbial region; another mark in W-shape on shoulder, and an inverted V-shape or Y-shape in posterior part of dorsum; some large, dark brown spots on posterior part of dorsum and along dorsolateral region; these markings sometimes enlarged and connected, forming dark brown marbling or reticulation on dorsum; loreal area with a dark brown stripe, enlarged and covering nostril region; another stripe below supratympanic fold; upper lip with some dark brown bars; a large, dark brown patch in tympanum region; a large, black blotch in posterior part of flank, connecting with V-shape or Y-shape marks on dorsum; chin and throat reddish brown, mottling with small white spots, more dense at margin; chest reddish brown with white marbling; belly reddish brown with small white spots, anterior part with white marbling and dark brown spots; dark brown dorsal surface of limbs with distinct transverse cross-bars, indistinct on upper arm; tips of fingers and toes flesh colored; supra-axillary gland copper; axillary and femoral glands white; iris with thin, black reticulation throughout, coppery red dorsally and fading to pale silver ventrally; pupil vertical and black (identification followed Rowley et al., 2011b).

Sexual dimorphism. Internal vocal sac present in males.

Taxonomic remarks. Some specimens of the collection differ from the original description of Rowley et al., (2011b): the male specimen DT0771 has a white gland on posterior part of belly, near to groin; the male specimen DT0772 has four white glands along dorsolateral region and a group of three small, white glands on dorsoposterior level of insertion of forearm into the body (not mentioned by Rowley et al., 2011b).

Distribution. Species of *L. bidoupensis* was recently discovered from an evergreen forest, Lam Dong Province, Vietnam (Rowley et al., 2011b). Its appearances seem associated with small stream in forests. In Langbian Plateau, this species occurred at elevations from 577 m to 1935 m. These are new provincial records of this species from Dak Nong, Ninh Thuan, and Binh Thuan provinces.

***Ophryophryne hansi* Ohler, 2003**

English name: Han's Mountain Toad

Vietnamese name: Coc Nui Han-xi

(Plate 2. G—I)

Examined specimens. DT0248 (female) was collected at 12°212795 N, 108°699444 E, alt. 1399 m, in BDNB NP, on 28 Mar 2010; DT0275 (female) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; AMNH17565 (male) & AMNH17520 (female) were collected near to 11°49416 N, 108°53942 E, alt. 791 m, in SLSM, on 05 August 2011; AMNH17581, AMNH17588, AMNH17672 (male) were collected near to 11°27788 N, 108°21151 E, alt. 200 m, in SLSM, on 06 August 2011; AMNH16849—50, AMNH16852 (males) & AMNH16851 (female) were collected near to 11°27475 N, 108°21089 E, alt. 200 m, in SLSM, on 12 August 2011; AMNH16868 (male) was collected near to 11°29187 N, 108°21502 E, alt. 571 m, in SLSM, on 13 August 2011; AMNH16903—04 (males) were collected near to 11°28296 N, 108°29623 E, alt. 272 m, in SLSM, on 17 August 2011; AMNH16966 (male) was collected near to 11°27734 N, 108°30383 E, alt. 374 m, in SLSM, on 24 August 2011; DT0775 (females) were collected near to 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 18 July 2010; and DT0838 (female) was collected near to 11°907119 N, 108°015497 E, alt. 997 m, in TD NR, on 21 December 2010.

Diagnosis. Relative large-size *Ophryophryne* with large head; protruding supraorbital horn; dorsal coloration dark grey; pupil in vertical diamond shape (after Ohler, 2003).

Morphological characters. Size medium to large, SVL 38.5—46.8 mm in males (n = 11), 22.5—62.0 mm in females (n = 6); head wider than long, 0.28—0.35 times of SVL; snout protruding to lower jaw in profile, SNL/SVL 0.25—0.39; loreal region not concave; nostril round; IO/UEW 0.88—1.23; eye large, noticeable with supraorbital horn; tympanum round; supratympanic fold distinct.

Fore limbs with arm shorter than hand length; relative finger length: I < II < IV < III; tips of fingers round; fingers free of webbing; callous bumps on fingers low; metacarpal tubercles indistinct; inner metacarpal low and elongated; thigh as long as tibia, approximate half of SVL; relative toe length: I < II < V < III < IV; the fourth toe length shorter than half of foot length; tips and callous bumps of toes similar to those of fingers; toes poorly webbed; inner metatarsal tubercle flat and elongated; outer metatarsal tubercle and tarsal fold absent.

Skin of head and dorsum finely granular; upper part of flank with round glandular warts; skin of ventral surface smooth; dorsal surface of limbs smooth with small glandular warts, more dense on thigh; tarsus smooth; axillary and femoral glands present.

Coloration in life. Dorsal surface of body and limbs light brown or grey with a triangular, dark grey mark in occiput region; dark grey or dark brown speckles on dorsum; transverse dark grey or dark brown bars on limbs present; lateral head and flank dark brown; upper lip with dark brown bars; supratympanic fold edged below by a dark brown or dark grey stripe; lower part of flank with dark brown spots, unequal in size; chin, throat, and chest smoky grey or brown with or without dark brown speckles; belly and ventral surface of thigh white or yellow, with dark grey or dark brown marbling; rear part of thigh white or yellow with dark brown marbling; a triangular, dark brown patch on vent and partly covered at the back of thigh; glands whitish (identification after Ohler, 2003).

Sexual dimorphism. Nuptial pads on the first and second fingers and inner vocal sac present in males; females with glandular warts, developed as a fleshy flap above cloaca.

Taxonomic remarks. The examined specimens differ from the original description (Ohler, 2003) by having: body size 28.5—46.8 mm, n = 11 (35.3—53.5 mm in Ohler's description); pupil in vertical diamond shape; interorbital more or less wider than upper eyelid's width (versus IO/UEW 0.72); tympanum distinct, round, TD/ED 0.47—0.76, E-T/TD 0.71—1.32 (versus tympanum oval, its diameter smaller than half eye diameter and smaller than distance to eye); toe webbing formula: $I_{2-2½}II_{2-3¼}III_{3-4}IV_{4-2½}V$ (versus $I_{2-2½}II_{2-3¼}III_{3-3½}IV_{3½-2½}V$); inner metatarsal tubercle flat and elongated, its length shorter than that of the first toe (versus inner metatarsal tubercle as long as the first toe); tibiotarsal articulation reaching to tympanum to eye; heels not in contact or touching when hind limbs folded at right angles to body (not mentioned by Ohler, 2003).

Distribution. *O. hansi* has been known only from Indochina, including Cambodia, Laos, and Vietnam. In Vietnam, this species was found in Central Highlands, in Ha Tinh, Quang Binh, Thua Thien Hue, Quang Nam, Quang Ngai, and Kon Tum provinces (Stuart et al., 2006; Nguyen et al., 2009; Frost, 2013). These are the first records of this species from Lam Dong, Dak Nong, and Binh Thuan provinces, at elevations from 200 to 1494 m. Occurrences of this species are limited in forests.

***Xenophrys major* (Boulenger, 1908)**

English name: Anderson's Spadefoot Toad, Anderson's eyebrow toad, White-lipped Horned Toad

Vietnamese name: Coc Mat Ben

(Plate 2. J—L)

Examined specimens. DT0009—10 (males) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0195, DT0203 (males) were collected at 12°212649 N, 108°696138 E, alt. 11387 m, in BDNB NP, on 26 March 2010; DT0272 (male) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in

BDNB NP, on 20 April 2010; DT0620 (male) & DT0615 (female) were collected at 12°190473 N, 108°352389 E, alt. 919 m, in BDNB NP, on 9 June 2010; DT0637 (male) was collected at 12°208745 N, 108°460867 E, alt. 1069 m, in BDNB NP, on 11 June 2010; DT0427 (male) was collected at 12°236175 N, 108°448397 E, alt. 745 m, in BDNB NP, on 19 June 2010; DT0567 (male) was collected at 12°445554 N, 108°44317 E, alt. 970 m, in CYS, on 03 June 2011; DT0439 (female) was collected at 12° N, 108° E, alt. m, in PB NP, on 24 September 2011; DT0488 (female) was collected at 11°8589 N, 107°999 E, alt. 910 m, in TD NR, on 15 April 2011; DT0489 (female) was collected at 11°857008 N, 108°003848 E, alt. 1029 m, in TD NR, on 15 April 2011; DT0492 (male) was collected at 11°852202 N, 108°00627 E, alt. 1198 m, in TD NR, on 17 April 2011; DT0733—35 (males) were collected at 12°838785 N, 107°894502 E, alt. 720 m in TD NR, on 17 June 2011.

Diagnosis. Size medium to large; eye large; fingers free; callous bumps being on fingers; toes poorly webbed; axillary and femoral glands present.

Morphological characters. Size medium to large, SVL 56.8−72.8 in males (n = 15), 50.5−80.7 mm in females (n = 3); head as long as wide, HL/SVL 0.37−0.43; snout pointed in dorsal view; nostril round, midway between tip of snout and eye; canthus rostralis sharp; loreal region oblique and concave; eye large, ED/SNL 0.79−1.18; interorbital depressed, IO/UEW 0.90−1.44; tympanum distinct, vertical oval, TD/ED 0.32−0.46; E-T/TD 1.37−2.68; supratympanic fold prominent; tongue round behind, free at rear for 0.13−0.41 times; vomerine teeth present; choanae partly exposed under upper jaw's ridge.

Relative finger length: I < = II < IV < III; tips of fingers and toes blunt, swollen; fingers free of webbing; callous bumps on fingers clear; inner metacarpal tubercle flat, at base of thumb; tibiotarsal articulation extending to tip of snout; heels overlapped when hind limbs folded at right angles to body; relative toe length: I < II < V < III < IV; tips of toes with flat, round discs without circummarginal grooves; toes webbed at base, $I_{2-2½}II_{2-3¼}III_{2½-3¾}IV_{4-1½}V$; inner metatarsal tubercle flat, its length half of the first toe length; outer metatarsal tubercle absent.

Dorsal skin smooth with a dark brown ridge, in “Y-shape” running from level above anterior of tympanum to middle of dorsum; an inverse “Y-shape” ridge, running from level of rump forward to middle of dorsum connected with the anterior ridge, a thin and low pair of dorsolateral folds, running from level of posterior tympanum to rump; flank with tubercles; axillary glands swollen, round; femoral glands present at the back of thigh, closer to knee than to vent.

Coloration in life. Back light brown to yellowish orange or lavender grey or olive grey, with some large and dark brown ridges; some dark brown spots, in different shapes, present in anterior part of head; a dark brown triangle present between eyes, backward to posterior part of head, terminating with a short line at level above tympanum; dorsal ridges dark brown; dorsum with some blurry, brown patches, various in sizes and shapes; dorsal granules dark brown; lateral head dark brown or olive brown; a long, continuous or broken, white to bright orange patch on upper lip, from rear of nostril to rictus; upper part of flank light brown, staining with orange, lower part pinky white; top of granules on flank yellowish white; belly white or yellow with reddish to dark brown blotches; limbs above light brown with black granules; cross-bars on limbs thin, dark brown; surface of humeral region reddish to dark brown; front of thigh blotchy; axillary and femoral glands white (identification followed Taylor, 1962).

Sexual dimorphism. Nuptial pads present at the first and the second fingers of the males (after Taylor, 1962).

Distribution. *X. major* is a widespread species in Asia, from India, China, southwards to Cambodia (Frost, 2013). In Vietnam, this species has been reported from Lao Cai, Ha Giang provinces in the North southwards to Dong Nai Province (Nguyen et al., 2009). In Langbian Plateau, this species was found at elevations between 720 and 1553 m, in forests and cultivated areas. These are new provincial records for Dak Nong, Ninh Thuan, and Binh Thuan provinces.

Microhylidae

Calluella guttulata (Blyth, 1856)

English name: Burmese Squat Frog, Blotxged Burrowing Frog

Vietnamese name: Enh Uong Dom

(Plate 3. A & B)

Photographs were taken from SLSM, near to 11°33979N, 108°26863E, alt. 100 m, on 17 August 2011.

Diagnosis. Habitus triangular; tympanum invisible; back reddish or dark brown with large, dark brown marking, various in shape, edged in light cream; pupil round (after Taylor, 1962).

Morphological characters. Habitus triangular; snout round in dorsal view; canthus rostralis undefined; tympanum invisible; supratympanic fold obvious.

Fore limbs short; fingers free, terminating with blunt tips; hind limbs short and robust; tips of toes similar to those of fingers; subarticular tubercles on toes prominent; inner metatarsal elongated.

Skin nearly smooth; posterior part of head with some large tubercles; flank smooth.

Coloration in life. Dorsal surface reddish or dark brown; head and dorsum masking by large, dark brown marking, various in shape, edged in light cream; tibia with dim dark brown transverse bars; two inner fingers white; ventral surface of foot and tarsus dark brown; pupil round, black (identification followed Taylor, 1962).

Sexual dimorphism. Dorsum dark brown in males, reddish in females. Vocal sac present in males.

Taxonomic remarks. The photographs show that the Vietnamese specimens differ from Taylor's (1962) description by having the flank immaculate reddish or dark brown dorsally and the venter

immaculate white or reticulated by brown spots (versus two defined spots at the groin in the afore mentioned description).

Distribution. *C. guttulata* has been known from Myanmar, Thailand, Laos, Cambodia, Vietnam, and Malaysia at elevations between 400—1000 m (Inger et al., 1999; Stuart, 1999; Stuart & Emmett, 2006; and Frost, 2013). In Vietnam, this species has been known from Gia Lai, Dak Lak, and Dong Nai provinces (Nguyen et al., 2009). This is the first report of this species from Binh Thuan Province, at elevation of 100 m.

Reproductive biology (Plate 12). A pair of this species in amplexus in a small pond in the forest of SLSM was encountered. This frog has the axillary amplexus pattern.

***Kaloula pulchra* Gray, 1831**

English name: Banded Bullfrog, Malaysian Narrowmouth Toad, Asiatic Painted Frog

Vietnamese name: Enh Uong Thuong

(Plate 3. C)

Photographs were taken from SLSM, on 23 August 2011.

Diagnosis. Habitus robust, in triangular shape; tympanum invisible; head and dorsum covered by a very large, dark brown marking; a pair of wide dark yellow stripes, running from behind the eye to groin.

Morphological characters. Body robust, in triangular shape; snout blunt in profile; canthus rostralis indistinct; nostril round; tympanum invisible; supratympanic fold present. Fore limbs long; tips of fingers round; hind limbs short, tips of toes round, swollen; toes poorly webbed.

Coloration in life. Upper head yellow-brown; dorsum covered by a very large, dark brown marking, from posterior orbital region to vent; a pair of wide dark yellow stripes, running from behind the eye to groin; lateral head yellow brown; upper part of flank dark

brown or grey, lower part light grey (identification followed Taylor, 1962).

Distribution. *K. pulchra* has been reported from India, Bangladesh, southern China to the Philippines in the South (Nguyen et al., 2009; Frost, 2013). This is a new provincial record of this species from Binh Thuan Province, Vietnam.

***Microhyla annamensis* Smith, 1923**

English names: Vietnam Rice Frog, Annam Narrow-mouth Frog, Minute Narrow-mouth Frog

Vietnamese name: Nhai Bau Trung Bo

(Plate 3. D)

Examined specimens. DT0012—13 (males) & DT0014—15 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0152—53, DT0160 (males) were collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 19 March 2010; DT0643 (female) was collected at 12°252838 N, 108°441305 E, alt. 641 m, in BDNB NP, on 12 June 2010; DT0517—18 (males) were collected at 12°173601 N, 108°698657 E, alt. 1504 m, in BDNB NP, on 24 June 2011; DT0528 (male) was collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 05 June 2011.

Diagnosis. Size small, SVL approximately 20 mm; tympanum invisible; skin with tubercles; outer metatarsal tubercle absent (after Taylor, 1962).

Morphological characters. Size small, SVL 16.0—19.8 mm in males (n = 9), 18.2—19.8 mm in females (n = 3); head as long as wide; snout pointed in dorsal view, pointed and exceeding beyond to lower jaw in profile; canthus rostralis rounded; loreal region oblique; nostril closer to tip of snout than to eye; IO/UEW 1.5—2; tympanum indistinct; supratympanic fold distinct; vomerine teeth absent; choanae partly concealed under margin of upper jaw; tongue round and free behind for 0.3—0.5 times of its length.

Fore limbs slender; relation of finger length: I < II < IV < III; fingers ended with round discs having thin grooves; fingers poorly webbed, formula: $I_{2-2}II_{2-3½}III_{3-3}IV$; subarticular tubercles on fingers round and prominent; inner metacarpal tubercle oval; outer metacarpal tubercle round and flat; tibiotarsal articulation extending to nostril; heels overlapped when legs are folded at right angles to body; relation of toe length: I < II < III < V < IV; tips of toes with round discs, larger than those of fingers; toe webbing moderately developed, formula: $I_{1-2}II_{1-2}II_{2¾-3}IV_{2¾-1½}V$; subarticular tubercles conspicuous; inner metatarsal tubercle oval and flat; outer metatarsal tubercle and tarsal fold absent.

Dorsal skin with tubercles; tubercles pointed on upper eyelid; upper part of flank resembling dorsum; lower part of flank and ventral surface smooth or granular.

Coloration in life. Above dark brown or dark grey; two V-shape, dark brown marks present behind orbital region and rear of dorsum; two pairs of dark brown spots above axilla and groin; few dark brown patches in vent region; tubercles on dorsum and flank white; lateral head and flank dark brown; the oblique fold yellow brown; venter white, heavily pigmented with grey or brown dots; chin dark grey; cross-bars on limbs distinct, dark brown; tips of fingers and toes grey brown (identification after Taylor, 1962).

Sexual dimorphism. Vocal sac present in males.

Taxonomic remarks. The specimens differ from Taylor's (1962) description by having ratio of ED/SNL 0.51—1.37 (versus ED shorter than SNL); iris brown with thin brown reticulation; pupil round, black (not mentioned by Taylor, 1962).

Distribution. *M. annamensis* has been reported from localities around Annamite mountains, including Indochina (Cambodia, Laos, and Vietnam) and Thailand, at elevations between 400—1200 m (Stuart, 1999 & Frost, 2013. In Vietnam, this species is widespread from Thanh Hoa, Ha Tinh, southward to Lam Dong and Dong Nai provinces (Nguyen et al., 2009). My records extend the altitudinal range of this species up to 1553 m.

***Microhyla berdmorei* (Blyth, 1856)**

English name: Berdmore's Narrow-mouthed Frog

Vietnamese name: Nhai Bau Bec-mo

Examined specimens. DT0382, DT0380, DT0284 (males) were collected near to 12°179743 N, 108°695955 E, alt. 1484, in BDNB NP, on 21 April 2010; and DT0521 (female) was collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 24 June 2011.

Diagnosis. Size medium; tympanum invisible; the first finger much shorter than the second; hind limbs long, with tibiotarsal articulation reaching to or beyond tip of snout (after Taylor, 1962).

Morphological characters. Size medium, SVL 29.25—31.81 mm in males (n = 3), 36.1 mm in female (n = 1); head as long as wide; snout round in dorsal view, protruding to lower jaw in profile, SNL/HL 0.34—0.42; canthus rostralis rounded; loreal region nearly vertical; nostril round, closer to tip of snout than to eye; eye diameter equal to snout length; interorbital distance as broad as upper eyelid width; tympanum covered by skin; supratympanic fold indistinct; vomerine teeth absent; choanae round, small, and completely exposed; tongue round and free behind.

Relation of finger length: I < II < IV < III; tips of fingers enlarged into round discs, with peripheral grooves; fingers free of webbing; subarticular tubercles on fingers conspicuous; two palmar tubercles large and oval, the outer larger and strongly notched; tibiotarsal articulation extending beyond to tip of snout; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes larger than those on fingers; toes fully webbed; inner metatarsal tubercle prominent and long; outer metatarsal tubercle round, conspicuous, distinctly separated from the inner; tarsal fold thin and low.

Skin smooth with tubercles and ridges on dorsum and flank; tubercles on flank larger and denser than those on dorsum.

Coloration in life. Back grey with dark brown markings; a triangular mark extending from interorbital region to shoulder; a large, irregular shape, dark grey mark on dorsum; cross-bars on limbs present; underside whitish with dense brown pigments on chin, throat, and chest; behind of thigh whitish marbling with brown; vent region dark brown (identification followed Taylor, 1962 & Berry, 1975).

Sexual dimorphism. Males with two external vocal sacs with a distinct cross fold.

Taxonomic remarks. The specimens differ from previous descriptions as follows: tongue free for 0.32—0.36 times of its length (versus tongue free for one half of its length in Taylor's description, 1962); the specimens have webbing reaching to between distal subarticular tubercle and disc and reaching to distal subarticular tubercle of the fourth toe (versus toes webbed to terminal discs in the descriptions of Taylor, 1962 & Berry, 1975); and dermal ridges along outer margins of the first and fifth toes present (not mentioned by Taylor, 1962 & Berry, 1975).

Distribution. This species has a wide distribution, from India, Bangladesh, China, Myanmar, Thailand, Laos, Vietnam, Cambodia, Malaysia, Sumatra and Borneo (Frost, 2013). In Vietnam, it has been recorded from Son La, Hoa Binh, Ninh Binh, Quang Binh, Thua Thien Hue, Quang Nam, Kon Tum, Gia Lai, Dak Lak, Lam Dong, Dong Nai, Ba Ria - Vung Tau provinces (Nguyen et al., 2009). In Langbian Plateau, this species was encountered at elevations up to 1500 m.

Microhyla heymonsi Vogt, 1911

English name: Black-flanked Pigmy Frog, Taiwan Rice Frog

Vietnamese name: Nhai Bau Hay-mon

(Plate 3. E)

Photographs were taken from SLSM near to 11°27475 N, 108°21089 E, alt. 200 m & SLSM, Binh Thuan Province in August 2011.

Diagnosis. A small microhylid, SVL about 22 mm; dorsum grey or brown with one or two small black spots and a thin, median white line running from tip of snout to vent; lateral head and body black; tympanum invisible (after Taylor, 1962).

Morphological characters. Size small; head small; snout pointed, round at tip in dorsal view, protruding beyond lower jaw in profile; nostril round, closer to tip of snout than to eye; tympanum invisible; heels overlapped when hind limbs folded at right angles to body; thigh longer than tibia; skin smooth; internal vocal sac present in males.

Coloration in life. Back yellow brown with a thin white line running along dorsum; a dark brown spot present on the middle of dorsum; lateral head and body completely or dorsally dark brown; cross-bars on limbs present (identification followed Taylor, 1962 and Berry, 1975).

Taxonomic remarks. a large, hourglass-shape, brown mark extending from interorbital region to anterior part of dorsum; another mark in inverse butterfly-shape being on posterior part of dorsum; the marks on dorsum distinct or blurry; iris bright bronze with dark brown reticulation; pupil round, black (not mentioned in the descriptions of Taylor, 1962 and Berry, 1975).

Distribution. This species has been reported from India, China, Laos, Thailand, Cambodia, Vietnam, Malaysia, and Indonesia (Frost, 2013). *M. heymonsi is a* common species in Vietnam. Its occurrences spreads from Lao Cai and Ha Giang in the North southwards to Kien Giang and Ca Mau in the South (Nguyen et al., 2009). This is the first record of this species from Binh Thuan Province, Vietnam.

***Microhyla pulchra* (Hallowell, 1861)**

English names: Guangdong Rice Frog, Marbled Pigmy Frog, Yellowlegged Pigmy Frog

Vietnamese names: Nhai Bau Van, Enh Uong Nho

(Plate 3. F)

Photographs of male frogs were taken from opening habitat of corn farm, near to 11°23563 N, 108°27703 E, alt. 115 m, in SLSM, Binh Thuan Province.

Diagnosis. Habitus triangular; tympanum invisible; the first finger much shorter than the second; tips of digits not enlarged; heels overlap when legs are folded at right angles to body (after Taylor, 1962).

Morphological characters. Body triangle shaped, small; snout round in dorsal view, protruding in profile; nostril round, closer to tip of snout than to eye; canthus rostralis indistinct; eye large; tympanum invisible; internal vocal sac present in males; fore limbs short.

Coloration pattern noticeable with a dark brown cross-bar between orbit; large, diagonal, alternative dark brown and light brown parallel lines, forming an A-shape on head and anterior part of dorsum, extending to groin, and smaller, dark brown posteriorly; posterior part of dorsum with some large dark brown blotches, in irregular shape; transverse bands on limbs distinct; groin, anterior and posterior parts of thigh bright yellow; chin and throat dark grey (identification followed Taylor, 1962 and Berry, 1975).

Sexual dimorphism. Males with internal vocal sacs.

Taxonomic remarks. Iris bronze with dark grey reticulation; pupil round, black (not mentioned by Taylor, 1962).

Distribution. *M. pulchra* has been known from India, China, Thailand, Laos, Cambodia and Vietnam (Frost, 2013). This is the first record of *M. pulchra* from Binh Thuan Province, Vietnam.

***Microhyla* sp. 1**

(Plate 3. G)

Examined specimens. DT0188, DT0191 (males), DT0189—90 (females) were collected at 12°212649 N, 108°696138 E, alt. 1387 m, in BDNB NP, on 26 March 2010; DT0234, DT0237 (males) were collected at 12°212795 N, 108°699444 E, alt. 1399 m, in BDNB NP, on 28 March 2010; DT0515—16 (males) were collected at 12°173601 N, 108°698657 E, alt. 1504 m, in BDNB NP, on 24 June 2011; DT0802 (female) was collected at 12°417312 N, 108°375496 E, alt. 1133 m, in CYS NP, on 30 may 2011; DT0578—79 (males) were collected at 12°42366 N, 108°350285 E, alt. 864 m, in CYS NP, on 01 June 2011; DT0529, DT0556—57 (males) were collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 04—05 June 2011.

Morphological characters. Habitus in triangular shaped; SVL 14.9—15.5 mm in males (n = 11), 23.1—24.3 mm in females (n = 3); snout pointed in dorsal view and truncated in profile; nostril round, closer to tip of snout than to eye; canthus rostralis sharp; eye large, ED/SNL 1.84; tympanum invisible; choanae; vomerine teeth absent; tongue round and free behind for 0.36−0.47 times of its length.

Fore limbs slender; relative finger length: I < II < IV < III; ends of fingers with round discs, bearing narrow peripheral grooves; fingers webbed, formula: $I_{2-2¼}II_{2-3¼}III_{2½-3}IV$; subarticular tubercles on fingers round and prominent; inner metacarpal tubercle oval and prominent; outer metacarpal tubercle round; hind limbs long; tibiotarsal articulation extending to eye or between eye and nostril; heels overlapped when legs are folded at right angles to body; tips of toes rounded; relation of toe length: I < II < III < V < IV; discs on toes slightly larger than those on fingers; toes fully webbed, formula: $I_{2-2½}II_{1¼-2½}III_{2-3½}IV_{3½-2½}V$; subarticular tubercles on toes similar to those on fingers but smaller; inner metatarsal tubercle long, prominent, and approximately half of the first toe length; outer metatarsal tubercle round and very distinct.

Dorsal skin with tiny tubercles, more dense on posterior part; lateral head and flank smooth; supratympanic fold distinct; dorsolateral edge sharp, oblique to groin and more flat posteriorly.

Coloration in life. Color of head and dorsum yellowish brown; back with a brown pattern, edged in dark brown, a thin white line at the middle; dorsum with a large dark brown spot in the middle, two on shoulder, and some small ones on posterior part; a large, butterfly-shape, dark brown mark on dorsum present or absent; lateral head light brown; a dark brown stripe, from tip of snout, through eye, enlarged to a triangular patch in temporal region; flank brown with a thick, dark brown dorsolateral stripe, enlarged at axilla level; chin and throat brown; a thin line running from chin to chest; belly yellowish white, sometimes with brown marbling; cross-bars on limbs indistinct; few dark brown patches present on dorsal surfaces of body, forearm and tibia; ventral thigh yellowish brown; anterior and posterior thigh dark brown; iris bronze; pupil round, black outlined with bronze circle.

Taxonomic remarks. The specimens differ from *M. fissipes* and *M. heymonsi* by having tongue deeply free at rear for more than one-third of its length (versus tongue free about one-fourth of its length in Taylor's 1962 description of *M. heymonsi*); tips of fingers slightly enlarged in to round discs (versus tips of fingers without discs in Taylor's description); hand with two palmar tubercles and lacking of supernumerary tubercles (versus three distinct palmar tubercles and supernumerary tubercles being on hand in *M. fissipes* and *M. heymonsi* in Taylor's 1962 description); dorsum with alternated, light and dark brown stripes, a thin mid-dorsal line and many dark spots (versus dorsum lacking stripes, lines, and spots in *M. fissipes* and dorsum nearly unicolor with a thin mid-dorsal line and few dark spots in *M. heymonsi* in the descriptions of Taylor, 1962 & Berry, 1975). The specimens also are very similar to *Microhyla* sp. 2. Differences between these two species are represented below.

Sexual dimorphism. Females larger than males. Gular pouches present in males

Distribution. This species was recorded at elevations around 860—1500 m, in Lam Dong and Dak Lak provinces, Vietnam.

Microhyla sp. 2

(Plate 3. H)

Examined specimens. DT0003 (male) was collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0071 (female) was collected at 12°094939 N, 108°660495 E, alt. 2027 m, in BDNB NP, on 21 March 2010; DT0145 (female) was collected at 12°096156 N, 108°660697 E, alt. 2004 m, in BDNB NP, on 18 March 2010; DT0265 (female) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0327 (male), DT0325—26, DT0328 (females) were collected at 12°194821 N, 108°712284 E, alt. 1908 m, in BDNB NP, on 26 April 2010; DT0351, DT0354, (males), DT0339, DT0356 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0355 (males), DT0352—53, (females) were collected at 12°196619 N, 108°712594 E, alt. 1942 m, in BDNB NP, on 27 April 2010; DT0411—12 (females) were collected at 12°101601 N, 108°66933 E, alt. 1781 m, in BDNB NP, on 10 June 2010; DT0981 (male) was collected at 12°153832 N, 108°463661 E, alt. 2048 m, in BDNB NP, on 07 August 2011.

Morphological characters. Habitus triangular shaped; size small, SVL 17.31—17.73 mm in males (n = 6) and 18.1—25.79 mm in females (n = 13); head as long as wide; snout pointed in dorsal view, protruding in profile; canthus rostralis sharp; loreal region oblique and concave; nostril round, closer to tip of snout than to eye; eye 0.62—0.90 times the length of the snout; tympanum invisible; supratympanic fold distinct or indistinct, sometimes arranged in a row; vomerine teeth absent; choanae round, partly concealed under margin of upper jaw; tongue round and free at rear.

Forelimbs slender; relative finger length: I < II < IV < III; tips of fingers with round discs, with peripheral grooves; fingers webbed at base,

$I_{2-2}II_{2-3¼}III_{3½-2}IV$; subarticular tubercles on fingers round and prominent; tibiotarsal articulation reaching to eye or to tip of snout; heels overlapped when legs are folded at right angles to body; relation of toe length: I < II < III < V < IV; tops and subarticular tubercles on toes similar to those on fingers but smaller in sizes; toes webbing well developed, formula: $I_{0-2}II_{0-2}III_{0-2½(1)}IV_{2¾(1)-0}V$; inner metatarsal tubercle distinct, its length equal to that of the first toe; outer metatarsal tubercle and tarsal fold absent.

Skin nearly smooth, with small tubercles on dorsum and smooth on ventral surface; edge of body at dorsolateral region very sharp, gradually flat posteriorly.

Coloration in life. Dorsal surface of head and dorsum yellowish brown; a dark brown triangular marking present between eyes and shoulder; back with a large dark brown marking, in butterfly-shape; a thin white line present or absent at the middle. Lateral head reddish to brown; loreal and upper lip dark brown; flank beige, blotched with dark brown or black near groin; blotches edged in cream or white, sometimes connected, forming a broken stripe along the dorsolateral edge; lower part brown with dark brown marbling; chin and throat yellowish to reddish brown with white spots; chest and belly with dark grey marbling or speckled in white; limbs brown with dark brown cross-bars above and dark grey marbling below; at the back of thigh orange yellow, with or without some dark brown spots; vent region dark brown; undersides of hand and foot dark brown; webbing of fingers and toes brown with dark grey marbling; iris bronze; pupil round, black with bronze circle outline.

Sexual dimorphism. Males smaller than females, with gular pouches.

Taxonomic remarks. The specimens have color pattern that strongly resemble *M. fissipes* and *M. ornata* but they differ from *M. ornata* in toe webbings that reach to discs except that on the fourth toe (versus webbing between toes reaching to or slightly beyond proximal tubercles of the toes in *M. ornata*, Kuramoto &

Joshy, 2006). Furthermore, *M. ornata* does not occur in Southeast Asia (Frost, 2013).

The specimens differ from *M. fissipes*, that quite commonly occurs in Southeast Asia, by having: IO/UEW 1.48−2.26 (versus interorbital wider than upper eyelid's width in Bourret's 1942 description); two palmar tubercles flat, the inner oval and the outer round (versus three metacarpal tubercles present in Taylor's 1962 description); toes fully webbed: $I_{0-2}II_{0-2}III_{0-2½(0)}IV2¾_{(0)-0}V$ (versus webbing between toes rudiment in the previous descriptions of Bourret, 1942; Taylor, 1962; Berry, 1975; and Kuramoto & Joshy, 2006); outer metatarsal tubercle absent (versus the two metatarsal tubercles present in the descriptions of Bourret, 1942; Taylor, 1962; and Berry, 1975); chin and throat dark brown with white spots or speckles; belly dark grey marling or speckled with white spots (versus ventral surface immaculate white in the description of Kuramoto & Joshy, 2006).

The specimens also differ from *Microhyla* sp. 1 in patterns of webbings of fingers and toes: $I_{2-2}II_{2-3¼}III_{3½-2}IV$ & $I_{0-2}II_{0-2}III_{0-2½(0)}IV_{2¾(0)-0}V$ (versus: $I_{2-2¼}II_{2-3¼}III_{2½-3}IV$ & $I_{2-2½}II_{1¼-2½}III_{2-3½}IV_{3½-2½}V$ in *M*. sp. 1) and in color pattern that lacks of alternating light and dark brown stripes, a mid-dorsal line, and dark brown sports on dorsum (versus dorsum with alternating light and dark brown stripes, a mid-dorsal line, and dark sports in *Microhyla* sp. 1).

Distribution. During the surveys, this small frog was found in the montane evergreen forests of BDNB NP, at about 1500−2027 m elev.

Dicroglossidae

Occidozyga lima (Gravenhorst, 1829)

English names: Green Puddle Frog, Common Puddle Frog, Aquatic Frog

Vietnamese name: Coc Nuoc San

(Plate 4. A)

Examined specimens. AMNH19611, AMNH16913 & AMNH16915 (males) were collected near to 11°24386 N, 108°27067 E, alt. 102 m, on 17 August 2011.

Diagnosis. Size small, SVL not exceeding 40 mm; skin very rough; tongue round posteriorly; tips of fingers pointed; toes fully webbed; a prominent tubercle present on tarsus (after Taylor, 1962).

Morphological characters. Size small, SVL 25.16−27.62 mm in males (n = 3); head small, broader than long; snout short, slightly round in dorsal view; nostril dorsal, midway between tip of snout and eye; internarial distance 0.19−0.21 times head width; canthus rostralis undefined; loreal region oblique and slightly depressed behind the nostril; eye large and prominent, ED/SNL 0.82; IO/UEW 0.68−0.84; tympanum visible; vomerine teeth absent; tongue long and pointed.

Fore limbs short; tips of fingers pointed; relative finger length: II < I < IV < III; fingers poorly webbed; subarticular tubercles on fingers small, very conspicuous; two palmar tubercles; hind limbs short, with tibiotarsal articulation reaching to tympanum or eye; toes pointed; subarticular tubercles on toes distinct; toes fully webbed; two metatarsal tubercles developed; tarsal fold distinct, modified by small tubercles; prominent tubercle being on heel; skin covered by tubercles which bear a spine on top except for chin which having folds.

Coloration in life. Dorsal surface of head and body olive with dark spots or flecks; a thin, whitish or yellowish line running along dorsum; upper part of flank olive, lower part light yellow with a dim, oblique, green streak in groin region; ventral surface white; chin and throat with two dark grey stripes; posterior part of thigh white with a dark grey stripe, running form vent to knee; a similar stripe extending from heel, along outer edge of tarsus and outer

toe; tubercles white (identification followed Boulenger, 1920; Taylor, 1962 and Berry, 1975).

Taxonomic remarks. The specimens closely resemble the previous descriptions of Boulenger (1920), Taylor (1962) and Berry (1975) except the tongue being free posteriorly for nearly half of its length (versus tongue free for two-thirds of its length in Taylor's 1962 description); iris bronze; pupil round and black (not mentioned by Boulenger, 1920; Taylor, 1962 and Berry, 1975).

Distribution. *O. lima* is a widespread species in India, Bangladesh, China, Myanmar, Laos, Thailand, Cambodia, Vietnam, Malaysia, and Indonesia (Frost, 2013). In Vietnam, this species has been known from Yen Bai, and Lang Son provinces in the North southwards to Kien Giang Province (Nguyen et al., 2009). This is a new record of *O. lima* from Binh Thuan Province. The specimens were found at the elevation of 102 m.

Occidozyga martensii (Peters, 1867)

English names: Marten's Frog, Marten's Puddle Frog, Marten's Oriental Frog

Vietnamese name: Coc Nuoc Mac-ten

(Plate 4. B)

Examined specimens. DT0573, DT0574, DT0575 (males) and DT0576 (female) were collected at 12°42366 N, 108°350285 E, alt. 864 m, in CYS NP, on 01 June 2011; DT0530, DT0558, DT0559, DT0560 (males) and DT0531 (female) were collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 04—05 June 2011; AMNH16842, AMNH16843, AMNH16844, AMNH17610 were collected near to 11°27475 N, 108°21089 E, alt. 200 m, in SLSM, on 06 & 11 August 2011; AMNH16912 & AMNH16914 (males) were collected near to 11°24386 N, 108°27067 E, alt. 102 m, in SLSM, on 17 August 2011; DT0683, DT0685, & DT0695 (females) were collected at 11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13 July 2010.

Diagnosis. Small; skin smooth with small tubercles; tongue round at rear; tips of fingers rounded; toes fully webbed (after Taylor, 1962).

Morphological characters. Size small, SVL 18.52—26.62 mm in males (n = 13), 30.35—33.87 mm in females (n = 5); head as long as broad; snout round in dorsal view; nostril nearly at midway between tip of snout and eye; canthus rostralis indistinct; loreal region concave; eye prominent, ED/SNL 0.99—1.19; IO/UEW 0.57—0.99; tympanum indistinct; fold in supratympanic region clear; choanae round, not hidden under ridge of upper jaw; tongue long, round at rear and free posteriorly for 0.47 times of its length.

Fore limbs short; relative finger length: II < I < IV < III; tips of fingers round, swollen; fingers free; subarticular tubercles on fingers round and well developed; inner metacarpal tubercle long, its length half of the first finger length; outer metacarpal tubercle, small, round; hind limbs moderate in length, with tibiotarsal articulation reaching to eye (to shoulder in females); heels not in contact when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; tips of toes similar to those of fingers; toes fully webbed, formula: I$_{0-0}$II$_{0-0}$III$_{0-1¼}$IV$_{1¼-0}$V; dermal ridges along outside of the first and fifth toes present; subarticular tubercles on toes distinct and prominent; inner metatarsal tubercle 0.59—0.76 times of the first toe length; outer tubercle absent; tarsal fold small and distinct.

Skin on head and anterior part of dorsum nearly smooth, with few small scattered white tubercles at posterior part of dorsum; side of head and flank finely granular; a dim fold, running from mouth angle backward to mandible edge; few small tubercles on upper part of flank; chin, belly, and ventral surface of thigh smooth; a fold present on chest; numerous small tubercles on limbs.

Coloration in life. Dorsal surface brownish grey or dark grey, speckled with dark brown; anterior part of dorsum dark brown than posterior part; two thick, light brown stripes in dorsolateral region, from rear of eye to region of rump, present or absent; a thin, light brown line, running along middle dorsum from front of eye to vent; similar lines on inner part of thigh and posterior part of tibia; these lines continuous when legs are folded at right angles to

body; dark brown patches on upper lip distinct or blurry; ventral surface white or yellowish white, marbling with light grey in chin, throat and chest regions (identification followed Taylor, 1962).

Sexual dimorphism. Nuptial pads present in males, covering dorsal, lateral, and partly ventral surfaces of the first fingers, 1.2—1.5 times in length of the first fingers.

Taxonomic remarks. The specimens differ from Taylor's description (1962) by having: relative finger length: II < I < IV < III (versus II = IV < I < III); nuptial pad yellowish white; iris light tan with dark grey reticulation; and pupil round, reddish brown with lighter ring outlined (not mentioned by Taylor, 1962).

Distribution. *O. martensii* has been reported from Southern China, Laos, Thailand, Cambodia and Vietnam (Frost, 2013). In Vietnam, it occurred in Lao Cai, Son La, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Thua Thien Hue, Quang Nam, Kon Tum, Gia Lai, Dak Lak, Dong Nai, Ba Ria - Vung Tau provinces (Nguyen et al., 2009). The distribution gap of this species is filled out in Dak Nong and Binh Thuan provinces, at elevations between 102—1262 m, by results of this study.

***Fejervarya limnocharis* (Gravenhorst, 1829)**

English names: Grass Frog, Field Frog, Rice Frog

Vietnamese name: Ngoe, Nhai

(Plate 4. C, D & G)

Examined specimens. DT0270 (juvenile) was collected at 12°182969 N, 108°67888 E, alt. 1494 m from BDNB NP, on 20 April 2010; DT0619 (female) was collected at 12°190473 N, 108°352389 E, alt. 919 m from BDNB NP, on 09 June 2010; DT0892 & DT0893 (males) were collected at 12°418102 N, 108°371515 E, alt. 999 m from CYS, on 27 May 2011; and DT0743 (male) was collected at 12°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 17 July 2010; and photographs taken from SLSM, in August 2011.

Diagnosis. Tips of digits not enlarged, swollen; the first finger longer than the second; toes moderately webbed; skin on dorsum with warts or numerous longitudinal glandular folds (after Taylor, 1962).

Morphological characters. Size medium to large, SVL 23.9—52.5mm in males (n = 4), 55.8 mm in female (n = 1); head longer than wide; snout pointed in dorsal view; nostril at middle between tip of snout and eye; canthus rostralis distinct, loreal region concave and oblique; eye large, ED/SNL 0.81, IO/UEW 0.57—0.90; tympanum distinct, TD/ED 0.39—0.58, E-T/TD 0.25—0.35; supratympanic fold distinct; vomerine teeth present, grouped in two oblique rows; tongue bifid at rear and free posteriorly for 0.37—0.52 times of its length.

Relative finger lengths: II < IV < I < III; tips of fingers round, slightly swollen; fingers lack webbing; subarticular tubercles on fingers round, conspicuous; inner metacarpal tubercle prominent, elongated; two outer metacarpal tubercles flat, the inner round, much larger than the outer which is long; tibiotarsal articulation reaching to eye or nostril; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < V < III < IV; tips and subarticular tubercles on toes similar to those on fingers; toe webbing well developed, formula: $I_{1-2}II_{1-2½}III_{1¾-3}IV_{3-1½}V$; inner metatarsal tubercle long, 0.67—0.73 times in length of the first toe; outer metatarsal tubercle small and round; tarsal fold absent.

Skin on dorsal surface granular with glandular folds; flank and ventral surface smooth.

Coloration in life. Ground color of dorsal surface yellow, brown or olive grey; a broad light brown bar between the eyes, sometimes followed by a dark brown bar; a large, light yellow mark, in X-shape in anterior part of dorsum; two wide, similar color bands along middle and posterior part of dorsum; dermal ridges on dorsum partly dark brown or reddish brown; dark brown patches or oblique bars present on lips; a large, dark brown patch covering most of tympanum; upper part of flank brown or olive grey, lower part white or whitish yellow; ventral surface white with dark brown

marbling on chin and throat; limbs with dark brown cross-bars, distinct (identification followed Boulenger, 1920 and Taylor, 1962).

Sexual dimorphism. Males have two external vocal sacs.

Taxonomic remarks. The specimens differ from previous descriptions by having a ratio of ED/SNL 0.70−0.85 (versus eye diameter equal to snout length in the description of Taylor, 1962); iris bronze; pupil dark brown or black (not mentioned by Boulenger, 1920 and Taylor, 1962).

Distribution. This species has a wide range in the Indo-Burma region including Myanmar, Thailand, Laos, Cambodia, Vietnam, Indonesia, Malaysia and border region of China (Frost, 2013). In Vietnam, this species is common entire the country (Nguyen et al., 2009). In Langbian, this species was found at elevations up to 1500 m.

Limnonectes dabanus **(Smith, 1922)**

English names: Annam Wart Frog, Toumanoff's Wart Frog

Vietnamese name: Ech Gay Do

(Plate 4. I—K)

Examined specimens. DT0738, DT0766—67 (males) & DT0781 (female) were collected at 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 17—18 July 2010. Photographs were taken from SLSM, in August 2011 and from PB NP on 18 August 2012.

Diagnosis. Body robust; size medium to large; head large with a large protruding on posterior of head; a pair of odontoids on lower jaw; fingers free, with round terminal discs; toes fully webbed.

Morphological characters. Body robust; size medium to large, SVL 41.6—57.0 mm in males (n = 3), 57.0 mm in female (n =1); head large, as long as wide, HL/SVL 0.42—0.55, with a noticeable protruding on occiput in males; snout round in dorsal view, round and much beyond to lower jaw in profile; canthus rostralis distinct, blunt; loreal region slightly oblique and concave; eye large, ED/SNL 0.61; IO/IN 0.79—1.08, IO/UEW 0.90—1.00; tympanum distinct,

round, TD/ED 0.60—0.90; supratympanic fold pronounced; vomerine teeth present, in two groups; tongue bifid at rear; a pair of odontoids being on lower jaw.

Fore limbs short; relative finger length: II < I < IV < III; fingers slender, free of webbing, terminating with small, round discs; subarticular tubercles on fingers moderate and prominent; inner metacarpal tubercle flat; two outer metacarpal tubercles, subequal in size, the inner round, the outer oval; tibiotarsal articulation reaching to eye; heels in contacted when legs are folded at right angles to body; relative toe length: I < II < V < III < IV; subarticular tubercles on toes similar to those on fingers; toes fully webbed; formula: $I_{0-1}II_{0-2}III_{1-2}IV_{2-1}V$; outer margins of the first and fifth toes with dermal fringes; inner metatarsal tubercles oval, conspicuous, its length 0.47—0.66 times that of the first toe; outer metatarsal tubercle and tarsal fold absent.

Skin on head dorsum smooth; tubercles on upper eyelid present; dorsum granular with pointed tubercles, more dense posteriorly; lateral head smooth, slightly granular in temporal region; upper part of flank similar to that on dorsum, lower part smooth; ventral surface smooth; dorsal surfaces of limbs with small, round tubercles.

Coloration in life. Ground color of dorsum yellow to brown or grey, outermost dark grey; tubercles on dorsum dark brown; a triangular pattern present between eyes, tip of snout light brown; a mid-dorsal stripe light yellow, extending from tip of snout to vent, sometimes absent; lateral head light brown or ground yellow; patches on lips blurry green to dark brown or light grey, the largest usually under the eye, indistinct in some individuals; some small indistinct brown flecks on upper part of tympanum; underside white; limbs with dark brown cross-bars (identification followed Bourret, 1942 & Stuart et al., 2006).

Sexual dimorphism. The protruding on head and odontoids on lower jaw are much more developed in males than in females.

Taxonomic remarks. The specimens differ from the description of Bourret (1942) by having a ratio E-T/TD 0.54—1.06 (versus ratio E-

T/TD 0.5—0.67). Iris tan with brown radius and reticulation; pupil round and red (not mentioned in the previous descriptions of Bourret, 1942 & Stuart et al., 2006)

Distribution. This species has been currently known from lowland of the Langbian Plateau, southern Vietnam and Cambodia at elevations below 900 m (Frost, 2013).

***Limnonectes poilani* (Bourret, 1942)**

English name: Poilan's Frog

Vietnamese name: Ech Poi-lan

(Plate 4. E, F & H)

Examined specimens. DT0193, DT0218, DT0224—25 (males) & DT0221, DT0223 (females) were collected at 12°214 N, 108°697775 E, alt. 1271 m, in BDNB NP, on 26—27 March 2010; DT0269 (male) & DT0266 (female) were collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0614 & DT0618 (females) were collected at 12°190473 N, 108°352389 E, alt. 919 m, in BDNB NP, on 20 April 2010; DT0633 (male) & DT0634, DT0641 (females) 12°208745 N, 108°460867 E, alt. 1069 m, in BDNB NP, on 11—12 June 2010; DT0655—7, DT0659 (female) 12°242169 N, 108°44895 E, alt. 697 m, in BDNB NP, on 16 June 2010; DT0676 (female) 12°240793 N, 108°452937 E, alt. 754 m, in BDNB NP, on 17 June 2010; DT0891 (female) 12°418102 N, 108°371515 E, alt. 999 m, in CYS NP, on 27 May 2011; DT0804 (female) 12°417312 N, 108°375496 E, alt. 1133 m, in CYS NP, on 28 May 2011; DT0459 (male) 12o041274 N, 108°738492 E, alt. 1166 m, in PB NP, on 27 September 2011; DT0702 (female), DT0682, DT0698, DT0705 (males) 11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13 July 2010; DT0741 & DT0744 (females) 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 17 July 2010; DT0850—2 (males) 11°907119 N, 108°015497 E, alt. 997 m, in TD NR, on 21 December 2010; and photographs taken from SLSM, in August 2011.

Diagnosis. Body stocky; size large; head large with two large swellings in occiput region; pair of odontoids present; tops of fingers and toes round, swollen; fingers free; toes fully webbed.

Morphological characters. Body stocky; size large, SVL 46.5—101.7 mm in males (n = 15), 33.3—106 mm in females (n = 18); head large, as long as wide; two swellings in occiput region; snout fairly pointed in dorsal view, pointed, sloping, and protruding in lateral view; nostril round, closer to tip of snout than to eye; canthus rostralis indistinct; loreal region sloping and concave; eye large, shorter than snout length; tympanum round and very distinct; supratympanic fold thickly prominent; vomerine teeth well developed, arranged in two oblique rows, lengths of the rows longer than distance between them; two tusks on lower jaw.

Tops of fingers round, swollen; fingers free; subarticular tubercles on fingers round and conspicuous; inner metacarpal tubercle oval; tibiotarsal articulation extending to eye or nostril; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; tops and subarticular tubercles on toes similar to those on fingers; toes fully webbed, formula: $I_{0-1}II_{0-2}III_{0-2}IV_{2-0}V$; dermal fringes on the outermost margins of the first and fifth toes; inner metatarsal tubercle distinct, 0.38—0.82 times in length of the first toe; outer metatarsal tubercle absent; tarsal fold dim.

Skin dorsally smooth or granular, with some large, round tubercles and short glandular folds; small tubercles and granules more dense on posterior part of dorsum; pointed tubercles on upper eyelid present; upper part of flank resembling the dorsum but with small tubercles, lower part smooth; ventral surface of body and limbs smooth.

Coloration in life. Top brown or dark grey; a light and dark brown bar crossing between upper eyelids; some dark brown or black patches or reticulations, covering part of dorsal tubercles; side of head light brown; large, dark brown patches on lips present; upper part of tympanum dark brown and lower half light brown; supratympanic fold dark brown; upper part of flank with some large, irregular shapes, dark brown blotches, lower part of flank

whitish or yellow; chin and throat white marbling with dark brown patches; chest and belly white or whitish yellow; cross-bars on back of limbs dark brown (identification followed Bourret, 1942).

Sexual dimorphism. The swellings on occiput and odontoids on lower jaw are much more prominent in males than in females.

Taxonomic remarks. The specimens disagree with Bourret's (1942) description in the following features: IO/UEW 0.67—1.44 and IO/IN 0.66—1.37 (versus internarial distance wider than interorbital distance which is broader than upper eyelid width); TD/ED 0.49—0.91 (versus tympanum larger than eye); iris bronze with brown reticulation; pupil round, reddish brown (not mentioned by Bourret, 1942).

Distribution. Occurrences of *L. poilani* have been reported from Cambodia and Vietnam, at elevations below 900 m (Frost, 2013). In Langbian Plateau, this species occurred in Lam Dong Province up to 1500 m. its appearances are restricted to forests. These are new provincial records of this species from Dak Nong and Ninh Thuan provinces, Vietnam besides the already known localities in Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Dak Lak, Lam Dong, Dong Nai provinces (Nguyen et al., 2009).

Reproductive biology (Plate 12). One couple in axillary amplexus was met in a rain filled pool, in the evergreen forest of TD NR, on 13 July 2010. The frog deposited eggs into water, in the middle of the water body. The pond was about 100 m^2 and 0.1−0.3 m in depth. There were 3−4 adult males appearing at the same place. It was light rain at the survey time. Temperature and humidity in the environment at the observed time were 22.3^oC and 80.6%, respectively. One female specimen was collected in gravid condition, bearing eggs that were bicolor white and dark grey in June 2011.

Ranidae

Hylarana attigua (Inger, Orlov, and Darevsky, 1999)

English name: Similar Frog

Vietnamese name: Ech At-tigua, Ech Dong Dang

(Plate 5. A—C)

Examined specimens. PB2 (male) & PB3 (female) were collected at 12°016316 N, 108°725385 E, alt. 931 m, in PB NP, on 25 September 2011; DT0895, DT0805, DT0812 & DT0814 (females) were collected near 12°417312 N, 108°375496 E, alt. 999—1133 m, in CYS NP, on 27—28 May 2011; DT0570, DT0547—48, DT0550—51, DT0555, DT0537 (males) were collected near 12°451146 N, 108°454748 E, alt. 880—970 m, in CYS NP, on 4—5 June 2011; DT0452 (male) was collected at 12°041274 N, 108°738492 E, alt. 1166 m, in PB NP, on 27 September 2011; DT0467 (male) was collected at 11°819028 N, 108°044821 E, alt. 1150 m, in TD NR, on 09 March 2011.

Diagnosis. Tips of fingers with small discs; dorsolateral fold present; outer metatarsal tubercle present; humeral gland present in males (after Inger at al., 1999; Stuart et al., 2006).

Morphological characters. Size medium to large, SVL 36.1—42.8 mm in males (n = 10), 39.9—56.6 mm in females (n = 5); head longer than wide, HL/SVL 0.37—0.45; snout pointed in dorsal view, pointed and protruding in profile; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region oblique and concave; IO/UEW 0.82—1.09; tympanum large, round, TD/ED 0.51—0.75; supratympanic fold absent; vomerine teeth in two oblique rows; tongue notched posteriorly.

Fore limbs slender; relative finger length: II < I < IV < III; tips of fingers with small, thick and oblong discs, circummarginal grooves absent on the first finger disc, indistinct on second, distinct on the two outers; fingers free of webbing; subarticular tubercles round, conspicuous; relative toe length: I < II < III < V < IV; discs of toes larger than those of fingers, bearing circummarginal grooves on

ventral surfaces; toes well webbed, formula: $I_{1-2}II_{1-2¼(½)}III_{1-3}IV_{2-1}V$; inner metatarsal tubercle elongated, 0.29—0.56 times in length of the first toe; outer metatarsal tubercle small, round, and prominent.

Skin smooth on dorsum, upper eyelid bearing small tubercles; dorsum with tubercles, denser posteriorly; dorsolateral fold moderately raised, from posterior eye near to vent; tubercles on limbs slightly larger than those on dorsum; upper part of flanks granular, lower part smooth; ventral surface of body and limbs smooth.

Coloration in life. Back orange to light brown or greenish brown, with or without dark brown spots; dorsolateral folds brown, edged by a dim brown line; tubercles on body white; lateral head brown; snout region dark brown or black; edge of upper lip light yellow; upper part of flank light brown, lower part white marbling with grey; chin and throat white, with or without dense dark brown pigments; belly white with light grey or light brown marbling; dorsal surface of limbs with brown cross-bars; posterior and ventral parts of thigh, tibia and tarsus bright orange; humeral gland white with brown speckles; fingers and toes light grey dorsally; webbings light grey to dark brown; iris bronze dorsally and reddish orange ventrally; pupil round, black (identification after Inger et al., 1999 and Stuart et al., 2006).

Sexual dimorphism. Males smaller than females, with humeral glands and nuptial pads; humeral gland enclosing nearly entire anterior part of upper arm; nuptial pad on dorsal, lateral and partly ventral surfaces of the first finger, from base of the finger to the level of distal edge of subarticular tubercle; ventral margin of the nuptial pad notch at level of distal edge of the inner metacarpal tubercle.

Distribution. *Hylarana attigua* has been reported from Cambodia, Laos, and Vietnam, at elevations between 510 and 1200 m (Inger et al., 1999). In Vietnam, this species has been known from the following provinces: Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue, Da Nang, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Dak Lak

(Nguyen et al., 2009). These are new provincial records of this species from Lam Dong, Dak Nong, and Ninh Thuan provinces, at elevations from 880 to 1553 m.

***Hylarana milleti* (Smith, 1921)**

English names: Dalat Frog, Millet's Frog

Vietnamese name: Chang Mi-le

(Plate 5. D—F)

Examined specimens. DT0381 (female) was collected near 12°179743 N, 108°695955 E, alt. 1484 m, in BDNB NP, in March 2010; DT0020—24 (males); DT0017, DT0019 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0391—92 (males) were collected at 12°2136 N, 108°698 E, alt. 1315 m, in BDNB NP, on 27 March 2010; DT0271 (female) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0295—96 (males) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 24 April 2010; DT0621 (female) was collected at 12°190473 N, 108°352389 E, alt. 919 m, in BDNB NP, on 09 June 2010; DT0429 (male) was collected at 12°1735 N, 108°7 E, alt. 1494 m, in BDNB NP, on 01 July 2010; DT0507 (male) was collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 21 July 2011; DT0896 (male) was collected at 12°418102 N, 108°371515 E, alt. 999 m, in CYS NP, on 27 May 2011; DT0552, DT0535—36, DT0538 (males) were collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 04—05 June 2011; DT0709, DT0711, DT0713 (males) were collected at 11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13 July 2010; DT0466 (male) was collected at 11°819028 N, 108°044821 E, alt. 1150 m, in TD NR, on 09 March 2011. Photographs were taken from PB NP in August 2012.

Diagnosis. Dorsal surface yellowish to orange brown or grey brown; lateral head dark brown, gradually fainting posteriorly into light grey; discs of fingers large, with cirummarginal groove; toe

webbing: $I_{2-2}II_{1¾-3}III_{2-3½}IV_{3-2}V$; humeral gland, and nuptial pad present in males.

Morphological characters. Specimens were identified as *Hylarana milleti* by having the following series of contributes: SVL 32.1—39.2 mm in males (n = 20), 41.6—43.2 mm in females (n = 5); head longer than wide; snout obtusely pointed in dorsal view; pointed and exceeding beyond lower jaw in lateral view; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region distinct and slopping; eye large, ED/SNL 0.61—0.89, IO/IN 0.82—1.10, IO/UEW 0.77—1.19; tympanum obvious, TD/ED 0.61—1.03, E-T/TD 0.11—0.4; supratympanic fold absent; vomerine teeth grouped in two oblique rows, their lengths shorter than distance between them.

Fore limbs slender; relative finger length: I < II < IV < III; fingers free of webbing; tips of fingers with flat discs, bearing circummarginal grooves; subarticular tubercles on fingers round and conspicuous; hind limbs long, with tiobiotarsal articulation reaching to nostril or tip of snout; heels overlapped when legs are folded at right angles to the body; relative toe length: I < II < V < III < IV; tips of toes similar to those of fingers but larger in sizes; toes webbed, formula: $I_{2-2}II_{1¾-3}III_{2-3½}IV_{3-2}V$; subarticular tubercles on toes prominent; outer metatarsal tubercle small, round, and conspicuous; tarsal fold absent.

Skin of head smooth; skin on dorsum, flank and back of limbs finely granular with small tubercles; dorsolateral fold thick and prominent, running from rear of eye near to vent; skin smooth ventrally.

Coloration in life. Dorsal surface yellowish to orange brown or grey brown, with or without indistinct white spots and dark brown markings; outer margin of dorsolateral fold underlined by a thin, dim brown stripe; lateral head dark brown, gradually fainting posteriorly into the light grey; edge of upper lip bright yellow to whitish yellow; upper part of flank light grey, lower part white, staining with light grey; ventral surface of body and limbs yellowish white, front of belly light grey; dark brown cross-bars on limbs

distinct; iris bronze dorsally, reddish ventrally; pupil round and black (identification after Smith, 1921; Bourret, 1942; Inger et al., 1999; and Stuart et al., 2006).

Sexual dimorphism. Males with internal vocal sacs, humeral glands, and nuptial pads. Humeral gland highly raised on anterior surface of upper arm. Nuptial pad present on dorsal, lateral, and partly ventral surfaces of the first finger; ventral margin of nuptial pad strongly notched at level distal edge of inner metacarpal tubercle or divided into two separated parts (after Inger et al., 1999; Stuart et at., 2006).

Taxonomic remarks. The specimens differ from Smith's (1921) description in length of inner metatarsal tubercle half of the first toe length (versus inner metatarsal tubercle 2.5—3.0 times in length of the first toe).

Distribution. *H. milleti* has been known from China, Laos, Cambodia, Thailand, and Vietnam, at elevations of 510—2000 m (Smith, 1921; Inger et al., 1999; Stuart et al., 2006; and Frost, 2013). In Vietnam, this species was found in Central Highlands, including Thua Thien Hue, Da Nang, Quang Nam, Kon Tum, Gia Lai, Dak Lak, and Lam Dong provinces (Nguyen et al., 2009). This is the first record of *H. milleti* from Dak Nong Province, southern Vietnam.

Reproductive biology (Plate 12). This species has the behavior of congregating for breeding. A population of about 25−50 individuals that appeared together around small rain puddles, conducted advertisement calling for mating was observed in an evergreen forest, in TD NR on 15 July 2010. The puddles were about 0.5−2 m in width, 0.1−0.2 m in depth. The smallest distance between two calling frogs was about 0.3−0.5 m. The air temperature and humidity at the survey time were recorded at 22.3^{o}C & 80.6%, respectively. Another smaller population, about 10 individuals, was also met in June 2011. Amplexus activities of this species were not encountered but two clusters of eggs considered to be from this species were seen on 18 March 2010. The eggs dark brown, about 2 mm diameter, grouped in cluster, floating on water surface, at or

among small rocks along margin of water body of a small pond, nearby a stream or in a rocky hole along the stream. A female that had eggs in 2 mm diameter, with bicolor yellow and black or dark brown was collected in April 2010.

***Hylarana montivaga* (Smith, 1921)**

English names: Langbian Plateau Frog, Chantaburi Stream Frog

Vietnamese name: Chang Mi

(Plate 5. G—I)

Examined specimens. DT0018 (male) was collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0112, DT0115, DT0118, DT0186 (males), DT0057—58, DT0068, DT0082, DT0084, DT0116—17, DT0119, DT0183, DT0187 (females) were collected near 12°096156 N, 108°660697 E, alt. 2004 m, in BDNB NP, on 20—23 March 2010; DT0228 (male), DT0226, DT0393 (females) were collected at 12°214 N, 108°697775 E, alt. 1271 m, in BDNB NP, on 27 March 2010; DT0282 (male), DT0279—80 (females) were collected at 12°179743 N, 108°695955 E, alt. 1484 m, in BDNB NP, on 21 April 2010; DT0310, DT0329—30 (females) were collected at 12°194821 N, 108°712284 E, alt. 1908 m, in BDNB NP, on 26 April 2010; DT0363—64 (females) were collected at 12°196619 N, 108°712594 E, alt. 1942 m, in BDNB NP, on 27 April 2010; DT0398—400, DT0404 (males) were collected near to 12°101872 N, 108°669482 E, alt. 1796 m, in BDNB NP, on 09—10 June 2010; DT0418 (male), DT0419, DT0423 (females) were collected near 12°077531 N, 108°679183 E, alt. 1647 m, in BDNB NP, on 12—14 June 2010; DT0424—25 (males); DT0426 (female) were collected at 12°213523 N, 108°698009 E, alt. 1335 m, in BDNB NP, on 18 June 2010; DT0977 (female) was collected at 12°15397 N, 108°467011 E, alt. 1975 m, in BDNB NP, on 06 August 2011; DT0597—98 (females) were collected near 12°40773 N, 108°394624 E, alt. 1617 m, in CYS NP, on 29—30 May 2011; DT0559 (female) was collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 06 June 2011; DT1043 (male), DT1042 (female) were collected at

12°454768 N, 108°395751 E, alt. 1604 m, in CYS NP, on 17 October 2011; DT0434, DT0442 (males) collected at 11°998053 N, 108°729327 E, alt. 616 m, in PB NP, on 23 September 2011; DT0964 (male), DT0958 & DT0965 (females) were collected at 11°856131 N, 108°037052 E, alt. 1932 m, in TD NR, on 25 July 2011. Photographs of this species from PB NP taken in August 2012.

Diagnosis. Dorsal surface yellowish brown to brown or light grey; two oblique dark brown stripes in front and rear of tympanum; humeral gland absent in males.

Morphological characters. The collected specimens resemble the original description of *Hylarana montivaga* (Smith, 1921) in the following characters: size large, SVL 24.6—53.1 mm in males (n = 17), 22.9—75.7 mm in females (n = 30); head longer than wide; snout pointed in dorsal view, pointed and protruding in profile; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region concave; eye large, ED/SNL 0.68—0.95; tympanum very distinct, diameter of tympanum smaller than that of eye; supratympanic fold absent; vomerine teeth in two oblique rows which are as long as distance between them and longer than choanae diameter.

Tips of fingers with enlarged oblong discs, with circummarginal grooves on ventral surface; fingers free of webbing; relative finger length: I < II < IV < III; subarticular tubercles on fingers pronounced; hind limbs well developed, with tibiotarsal articulation reaching to level between eye and nostril or beyond tip of snout; heels overlap when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs on toes similar to those on fingers but larger in sizes; toes fully webbed, formula: $I_{0-1}II_{0-2}III_{0-2}IV_{2-0}V$; inner metatarsal tubercle long; outer metatarsal tubercle and tarsal fold absent.

Skin on dorsal and lateral head and body smooth or granular, with some round tubercles; dorsolateral fold pronounced, running from rear of eye near to vent; dorsal surface of limbs granular, with low dermal folds; underside of body and limbs smooth, thigh bearing flat tubercle.

Coloration in life. Dorsal surface light to brown with dark brown or green spots, posterior part darker than anterior part; dorsolateral fold bordered below with a broken, dark brown or black stripe; lateral head brown or light pinkish brown; a thick, dark brown stripe, running along underside of canthus rostralis, followed by a thin line, below margin of eye, ending with a large, similar color patch on ventral part of temporal region; dark brown spots present along margin of upper eyelid; a thick, dark brown or black, oblique stripe, running from dorsolateral fold to rear of rictus gland; edges of lips light yellow or pink to light brown, with dark brown dots; rictus gland whitish yellow or pinkish yellow; upper part of flank brown to light lavender at the middle with dark brown spots, lower part yellowish white or whitish with brown dots; chin and throat white with or without heavily dark brown pigments; chest and one-third anterior part of belly white with or without medium to dark brown spots; two-thirds posterior part of belly immaculate white; cross-bars on limbs dark brown; ventral surface of limbs yellowish white; webbing grey brown dorsally; discs on fingers and toes light grey or white; subarticular tubercles white; iris light brown anteriorly and dark brown posteriorly; pupil large, round, and black.

Sexual dimorphism. Males have white nuptial pads on the first fingers.

Taxonomic remarks. The specimens differ from previous descriptions (Smith, 1921 & Stuart et al., 2011) in the following features: a wider range of head lengths (HL/HW 1.05—1.30 & HL/SVL 0.38—0.46, n = 47; compare to HL/HW 0.88—1.12 & HL/SVL 0.35—0.39 in the measurements of Smith, 1921), eye with IO/IN 0.73—2.40; IO/ UEW 0.77—1.40, IO/HW 0.21—0.38 (versus IO/IN < 1, IO/UEW ~ 1, IO/HW 0.23—0.29 in the mentioned descriptions), and tympanum with TD/ED 0.48—0.95 & E—T/TD 0.21—0.68 (versus TD/ED 0.50—0.69 & E-T/TD 0.4—0.67 in the mentioned descriptions); inner metatarsal tubercle short, 0.34—0.73 times the first toe length (versus inner metatarsal tubercle 2.5 times in length of the first toe in the description of Smith, 1921); choanae round, partly conceal by edge of upper jaw; tongue bifid at rear, at level

0.10—0.30 times of its length, free posteriorly for 0.23—0.51 times of its lengths (not mentioned by Smith, 1921); some specimens have skin of dorsal and lateral surfaces with tubercles, bearing tiny spines; and skin of ventral surface finely granular (versus tubercles on dorsum and flank round as mentioned above and ventral surface smooth in the description of Inger et al., 1999).

Distribution. Species of *H. montivaga* has been known from the type locality in the Langbian Plateau, Vietnam and neighboring areas in Laos and Thailand, at elevations ca. 700—1500 m (Smith, 1921; Inger, 1999; Stuart et al., 1999; Frost, 2013). *H. montivaga* is the most common frog of the Ranidae in the Langbian Plateau. This species could be encountered in the cloud forests, evergreen forests, and the mixed forests composed of hardwoods and bamboo. These are new provincial records of this species from Dak Nong, Dak Lak, and Ninh Thuan provinces, at elevations between 616 and 2108 m.

Reproductive biology (Plate 12). A population of about 30 individuals that gathered together in a small pond, near to a dry stream, in the evergreen forest of BDNB NP, was encountered on 12 June 2010. Temperature and humidity of the environment at the survey time were 17.5−19.6^{o}C and 90.6−94.6%, respectively. Gravid females were found in April and June. Eggs were up to 5 mm in diameter, with bicolor black and yellowish white.

Hylarana nigrovittata **(Blyth, 1856)**

English names: Black-striped Frog, Black-spotted Frog, Sapgreen Stream Frog

Vietnamese name: Ech Suoi

(Plate 5. J—L)

Examined specimens. DT0653, DT0654 (males) & DT0624 (female) were collected near to 12^{o}242169 N, 108^{o}44895 E, alt. 697 m, in BDNP NP, on 10—16 June 2010; DT0820—824, DT0826—829 (males) & DT0825, DT0830 (females) were collected in TD NR, on

21 December 2010; photographs of this species from SLSM, taken in August 2011.

Diagnosis. Snout pointed in dorsal preview; dorsum dark yellow or brown; flank greenish grey or brown, with dark brown patches; discs on fingers with peripheral grooves; toe webbing: $I_{0-2}II_{0-2}III_{0-2¼}IV_{2-0}V$; internal vocal sac, humeral gland, and nuptial pad present in males.

Morphological characters. Size medium, SVL 43.9—55.2 mm in males (n = 11), 48.7—54.7 mm in females (n = 3); head longer than wide; snout pointed in dorsal view, pointed and protruding lower jaw in profile; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region oblique and concave; ED/SNL 0.66—0.99; tympanum round, TD/ED 0.60—0.98; vomerine teeth in two oblique rows, as long as choanae length; tongue bifid at rear, free posteriorly for 0.32—0.52 times of its length.

Limbs slender; relative finger length: II < I < IV < III; tips of fingers swollen with peripheral grooves; fingers free of webbing; subarticular tubercles on fingers round and well developed; tibiotarsal articulation reaching to eye or tip of snout; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < III < = V < IV; discs on toes similar to those on fingers but larger in sizes; toe webbing well developed, formula: $I_{0-2}II_{0-2}III_{0-2¼}IV_{2-0}V$; subarticular tubercles on toes round and conspicuous; inner metatarsal tubercle flat, 0.33—0.63 times in length of the first toe; outer metatarsal tubercle round; tarsal fold absent.

Skin on dorsal head smooth; dorsum and upper limbs finely granular, with larger tubercles; flank granular with large, round tubercles; dorsolateral fold thick, running from back of eye near to rump region; two rictus glands present behind tympanum; ventral surface smooth; behind of thigh and regions surround vent with finely granular.

Coloration in life. Head and dorsum brown, with small dark brown spots or speckles; dorsolateral fold bordered below by a dark brown or black stripe; lateral head dark brown to black; snout

region light brown, reticulated in dark brown; canthus rostralis underlined by a thick, dark brown or black stripe; edge of upper lip light yellow with dark brown marbling; upper part of flank greenish grey or brown, with a row of dark brown patches, lower part of flank light grey; groin with dark brown reticulations; chin and chest white with or without condense pigments; underside of thigh yellowish; back of limbs greenish brown with dark brown cross-bars and spots; front and behind of thigh with dark brown reticulation; webbing dark brown to black; discs of fingers and toes brown above and light grey below; iris bronze on upper part and reddish on lower part; pupil round and black (identification followed Smith, 1921; Bourret, 1942; Taylor, 1962; Inger et al., 1999; and Stuart et al., 2006).

Sexual dimorphism. Males with internal vocal sacs, humeral glands, and nuptial pads. Humeral gland highly raised on three-fourths inner part of anterior surface of upper arm, whitish, with dark brown flecks. Nuptial pad light grey.

Taxonomic remarks. The specimens agree with previous descriptions (Smith, 1921; Bourret, 1942; Taylor, 1962; Inger et al., 1999; Ziegler, 2002; and Stuart et al., 2006) except for: IO/IN 0.81—1.12 & IO/UEW 0.98—1.28 (versus interorbital distance equal to upper eyelid's width and equal to or less than internarial distance in the description of Bourret, 1942; or interorbital distance less than upper eyelid's width in the description of Taylor, 1962).

Distribution. *H. nigrovittata* has a wide distribution in Asia, from India, Nepal, China, Myanmar, Laos, Thailand, Cambodia, Malaysia and Vietnam, at about 60—1800 m elev., (Smith, 1921; Inger et al., 1999; Stuart, 1999; Stuart et al., 2006; and Frost, 2013). In Vietnam, this species has been reported from provinces: Cao Bang, Lang Son, Phu Tho, Quang Ninh, Son La, Hoa Binh, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue, Da Nang, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Dak Lak, Dak Nong, Lam Dong, Ninh Thuan, Binh Phuoc, Dong Nai, Kien Giang (Nguyen et al., 2009). This is the first record of this species from Binh Thuan Province, south of Vietnam.

***Odorrana gigatympana* (Orlov, Ananjeva, and Ho, 2006)**

English name: Gigatympanum Frog

Vietnamese name: Ech Mang Nhi Khong Lo

(Plate 6. B)

Examined specimens. DT0833—35 & DT0877 (males) were collected at 11°907119 N, 108°015497 E, alt. 997 m, in TD NR, on 21—22 December 2010. Photographs were taken from PB NP, near to 12°113933 N, 108°740656 E, alt. 745 m, on 16 August 2012.

Diagnosis. Tympanum very large, subequal to eye; dorsum dark yellow with some light intermixed with dark brown speckles; skin on dorsum tubercular; dorsolateral fold present; fingers free of webbing, with round discs, bearing circummarginal grooves; toe webbing: $I_{0-1}II_{0-1}III_{0-1¾}IV_{1¾-0}V$ (after Orlov et al., 2006).

Morphological characters. The specimens resemble the original description of *Odorrana gigatympana* of Orlov et al., (2006a) in the following characters: size medium, SVL 30.1—31. 9 mm in males (n = 4); head longer than wide; snout pointed in dorsal view, pointed and proceeding beyond lower jaw in lateral view; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region oblique and concave; ED/SNL 0.67—0.83; IO/UEW 0.86—0.93; tympanum very large, TD/ED 0.84—1.15, E-T/TD 0.11—0.22; supratympanic fold prominent; vomerine teeth grouped in two oblique lines, closer to choanae than to each other; choanae small, round, partly hidden under the upper jaw's margin; tongue round notched behind; tongue free at rear for 0.34—0.42 times of its length.

Forearm slender; discs of fingers round, bearing peripheral grooves; the third finger disc smaller than tympanum diameter; fingers free of webbing; subarticular tubercles on fingers round and swollen; inner metacarpal tubercle distinct, as long as the first finger; hind limbs long; tibiotarsal articulation beyond tip of snout; heels strongly overlapped when legs held at right angles to body; discs and subarticular tubercles of toes similar to those of fingers;

toes well developed webbed; inner metatarsal tubercle long, half of the first toe length; outer metatarsal tubercle small and flat.

Skin on head finely granular; skin on dorsum and upper part of flank with tubercles; dorsolateral fold distinct, running from rear of eye to groin; lower part of flank and ventral surface smooth.

Coloration in life. Dorsal and lateral surfaces yellowish brown with some light or dark brown speckles; supratympanic and dorsolateral folds underlined by an interrupt, dark brown stripe; upper lip and rectus gland yellowish white, with or without dark brown speckles; canthus rostralis bordered by a dark brown stripe; temporal region with an oblique, dark brown stripe from post-ventral of eye backward to mandible edge, partly bordered tympanic rim; flank light brown with or without dark brown spots; ventral surface immaculate white or white speckled with dark brown spots on chin, throat, and chest; anterior and posterior surfaces of thigh light brown reticulated in dark brown; limbs with blurry, brown cross-bars; webbing grey; iris tan dorsally and reddish brown ventrally; pupil round and black.

Sexual dimorphism. Males with a pair of gular pouches and white or light grey nuptial pads.

Taxonomic remarks. The specimens differ from the original description (Orlov et al., 2006a) as follows: relative finger length: I < II < IV < III (versus the relative finger length: II < I < IV < III); relative toe length: I < II < III < V < IV (versus the relative toe length: I < II < V < III < IV); tarsal fold absent (versus tarsal fold poorly developed); dorsolateral fold low and broken (versus dorsolateral fold very well developed); dermal fringes along outer margins of the first and fifth toes narrow (not mentioned by Orlov et al 2006a).

Distribution. *O. gigatympana* is currently known from only the type locality of Kon Tum Province, Vietnam, at elevations of 1150—1250 m (Orlov et al., 2006a & Frost, 2013). This species seems to be restricted to the mixed forests composed of hardwoods and bamboo. This is new provincial records for this species from Dak Nong and Ninh Thuan provinces, at elevations of 393—997m.

***Odorrana graminea* (Boulenger, 1900)**

English name: Graminea Frog

Vietnamese name: Ech gra-mi-ne

(Plate 6. D—G)

Examined specimens. DT0037—38 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0151, DT0159 (females) were collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 19 March 2010; DT0194, DT0200—02 (females) were collected at 12°212649 N, 108°696138 E, alt. 1387 m, in BDNB NP, on 26 March 2010; DT0264, DT0268 (females) were collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0610—11, DT0613, DT0616—17 (females) were collected at 12°190473 N, 108°352389 E, alt. 919 m, in BDNB NP, on 09 June 2010; DT0627—29 (females) were collected at 12°211188 N, 108°444591 E, alt. 818 m, in BDNB NP, on 10 June 2010; DT0631, DT0638, DT0640 (females) were collected near to 12°208745 N, 108°460867 E, alt. 1069 m, in BDNB NP, on 11—12 June 2010; DT0645—48 (females) were collected at 12°252838 N, 108°441305 E, alt. 641 m, in BDNB NP, on 15 June 2010; DT0658, DT0661 (females) were collected at 12°242169 N, 108°44895 E, alt. 697 m, in BDNB NP, on 16 June 2010; DT0678 (male), DT0663, DT0665, DT0671—72, DT0674—75 (females) were collected at 12°240793 N, 108°452937 E, alt. 754 m, in BDNB NP, on 17 June 2010; DT0992 (male) was collected at 12°134272 N, 108°479302 E, alt. 1597 m, in BDNB NP, on 08 August 2011; DT0899—901 (males), DT0897—98 (females) were collected at 12°418102 N, 108°371515 E, alt. 999 m, in CYS NP, on 27 May 2011; DT0807 (male), DT0818 (female) were collected at 12°417312 N, 108°375496 E, alt. 1133 m, in CYS NP, on 28 May 2010; DT0801 (male), DT0588, DT0798—99 (females) were collected at 12°40773 N, 108°394624 E, alt. 1617 m, in CYS NP, on 30 May 2011; DT0731, DT0778 (males), DT0780 (females) were collected at 11°838785 N, 107°894502 E, alt. 720 m, in TD NR, on 17—18 July 2010; DT0832, DT0836, DT0840—43, DT0845—49

(males), DT0853 (female) were collected at 11°907119 N, 108°015497 E, alt. 997 m, in TD NR, on 21 December 2010; DT0878—80 (females) were collected at 11°90753 N, 108°016004 E, alt. 967 m, in TD NR, on 22 December 2010; DT0485 (male), DT0468 (female) were collected near to 11°8589 N, 107°999 E, alt. 910 m, in TD NR, on 09 March 2011; DT0490 (male) was collected at 11°819028 N, 108°044821 E, alt. 1150 m, in TD NR, on 16 April 2011; DT0491 (female) was collected at 11°858815 N, 107°999309 E, alt. 910 m, in TD NR, on 17 April 2011. Photographs were taken from PB NP, near to 12°093907 N, 108°747182 E, alt. 627 m, on 15 August 2012.

Diagnosis. Females much larger than males; dorsum green or brownish olive; skin smooth dorsally and ventrally; dorsolateral fold indistinct; fingers free of webbing; discs of digits large with circummarginal grooves; toes fully webbed.

Morphological characters. The collected specimens agree with description of *Odorrana graminea* by Bain et al., (2003) in the following characters: SVL 32.4—52.9 mm in males (n = 22), 49.9—101.1 mm in females (n = 45); head longer than wide; snout pointed or truncated in dorsal view, pointed or blunt and exceeding to lower jaw in lateral view; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region concave; tympanum distinct, TD/ED 0.37—0.72; supratympanic fold indistinct; vomerine teeth present, in two oblique rows; tongue bifid at rear, free posteriorly for 32—64 times of its length.

Relative finger length: II < I < IV < III; fingers free of webbing, tips with large discs, with circummarginal grooves; subarticular tubercles on fingers prominent; tibiotarsal articulation beyond tip of snout; heels strongly overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes similar to those on fingers; toes fully webbed, from distal phalanx to disc narrow as flap of skin; inner metatarsal tubercle prominent and long, 0.36—0.70 times in length of the first toe; outer metatarsal tubercle and tarsal fold absent.

Skin smooth above and beneath; dorsolateral fold indistinct; flank granular; cloaca opening unmodified.

Coloration in life. Dorsum green or brownish olive with or without spots; lateral head greenish brown; edge of upper lip golden; upper part of flank brownish olive or brown, lower part of flank greyish white; ventral surface whitish; transverse cross-bars on upper limbs brown; dorsal surface of discs light grey; dorsal tibia with few small, green flecks; webbing light grey; iris golden, staining with dark brown at position of around pupil; pupil round, black, bordered by golden ring.

Sexual dimorphism. Males much smaller than females, with a pair of gular pouches and white or grey nuptial pads on dorsal and lateral surfaces of the first fingers.

Taxonomic remarks. The specimens differ from the description of Bain et al. (2003) by having: ratios of ED/SNL 0.65—1.07 (versus ED/SNL 1.17) and IO/UEW 0.76—1.27 (versus interorbital narrower than upper eyelid width).

Distribution. *O. graminea* has been reported from China, Myanmar, Laos and Vietnam (Frost, 2013). In Vietnam, it occurred in Bac Kan and Lam Dong provinces (Nguyen et al., 2009). These are the first records of this species from Dak Lak, Dak Nong, and Ninh Thuan provinces, at elevations from 627 to 1617 m. This species is restricted to forests.

***Rana johnsi* Smith, 1921**

English name: John's Frog

Vietnamese name: Hiu hiu

(Plate 6. A)

Examined specimens. DT0728 (female) was collected at 11°835015 N, 108°00817 E, alt. 1262 m, in TD NR, on 13 July 2010.

Diagnosis. Skin smooth with well-defined dorsolateral fold; back yellow-brown; an oblique, light tan patch on lower part of temporal region; a dark brown patch present in tympanum area.

Morphological characters. An adult female agrees with previous descriptions of *Rana johnsi* (Smith, 1921; Inger et al., 1999 & Stuart et al., 2006) in the following features: SVL 51.71 mm; head longer than broad; snout pointed in dorsal view, pointed and projecting beyond lower jaw in profile; nostril round, closer to tip of snout than to eye; canthus rostralis sharp; loreal region oblique and concave; ED/SNL 0.87; IO/UEW 0.90; tympanum distinct, TD/ED 0.58; supratympanic fold low; vomerine teeth grouped in two oblique rows, longer than distance between them.

Relative finger length: II < I < IV < III; ends of fingers, round and swollen; fingers free of webbing; subarticular tubercles on fingers prominent; three palmar tubercles well developed; hind limbs slender; tibiotarsal articulation beyond tip of snout; heels strongly overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs of toes small, with peripheral grooves; toes webbed, formula: $I_{0-1½}II_{1-2}III_{0-2}IV_{2-0}V$; subarticular tubercles on toes developed; inner metatarsal tubercle oval and raised, half of the first toe length; outer metatarsal tubercle small, flat and round; tarsal fold absent.

Skin on dorsum smooth with well-defined dorsolateral fold, from rear of eye to rump; short oblique folds crossing thigh and tibia; venter smooth.

Coloration in life. Dorsal and lateral surfaces yellowish brown, with light brown blotches, head with a triangular light brown patch; lips white with light brown marbling; canthus rostralis underlined by a medium dark brown stripe; an oblique, light tan patch present in lower part of temporal region; a dark brown patch present between rear of eye and axilla; upper part of flank yellowish brown, with light yellow blotches, lower part of flank light tan or fawn; chin, throat, chest, and two-thirds anterior part of belly white with light grey speckles; one-third posterior part of belly immaculate white; limbs with narrow dark brown cross-bars.

Taxonomic remarks. The specimen differs from previous descriptions (Smith, 1921 & Stuart et al., 2006) as follows: ratio ED/E-T 4.75 (larger the ratio ED/E-T 3—4 times in the description of Smith, 1921); skin on dorsum smooth without tubercles or fold on shoulder (versus skin with few enlarge scattered tubercles and a glandular fold being between shoulders in the description of Stuart et al., 2006); cloacal region with dark brown patch; iris bronze dorsally and dark brown ventrally; pupil black (not described in the mentioned descriptions).

Distribution. This species has been reported from Cambodia, Lao, Thailand, Vietnam, China and Taiwan, at elevations between 700 and 1800 m (Smith, 1921; Inger et al., 1999 & Frost, 2013). This is the first provincial record of this species from Dak Nong Province, Vietnam. In Vietnam, this species has been known from Lao Cai, Ha Giang, Tuyen Quang, Cao Bang, Bac Kan, Thai Nguyen, Vinh Phuc, Phu Tho, Bac Giang, Hai Duong, Quang Ninh, Son La, Hoa Binh, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Kon Tum, Gia Lai, Lam Dong, and Dong Nai provinces (Nguyen et al., 2009).

Rhacophoridae

Chiromantis nongkhorensis (Cochran, 1927)

English names: Nongkhor Asian Treefrog, Nongkhor Pigmy Tree Frog, Nong Khor Bushfrog

Vietnamese name: Nhai Cay Nong-kho

(Plate 6. H)

Examined specimens. AMNH16916—19 (males) were collected from SLSM, near to 11°33979N, 108°26863E, alt. 100 m, on 17 August 2011.

Diagnosis. Habitus slender; size medium, up to 38 mm; dorsum yellow with dark brown spots; skin finely granular above and

coarsely granular on belly; skin of head not co-ossified to skull; fingers arranging in two groups; only two outer fingers webbed; only two outer fingers webbed (followed Taylor, 1962; Liem, 1970).

Morphological characters. Body slender; SLV 24.69—27.62 mm (males, n = 4); head longer than wide; snout truncated in dorsal view, pointed and protruding in profile; nostril closer to tip of snout than to eye; canthus rostralis sharp; loreal concave; eye large, IO/UEW 0.83—1.33; tympanum round, TD/ED 0.88, E-T/TD 0.38; supratympanic fold distinct; vomerine teeth absent; choanae round, small, almost hidden under upper jaw's edge; tongue bifid at rear and free behind for nearly half of its length.

Fore and hind limbs slender; relative finger length: I < II < IV < III; two outer fingers separated from two inner ones; tips of fingers with round discs, with circummarginal grooves; disc on the third finger equal to tympanum diameter; fingers webbed on the two outer only, formula: I–II–III$_{2-2}$IV; subarticular tubercles on fingers round and conspicuous; palmar tubercles flat; tibiotarsal articulation reaching to eye or to between eye and nostril; heels overlapped when legs are folded at right angles to body; tips and subarticular tubercles on toes resembling those on fingers but smaller in sizes; toes webbed, formula: I$_{1½-2}$II$_{1½-2¼}$III$_{1-2}$IV$_{1-0}$V; inner metatarsal tubercle flat, elongated, 0.64—0.77 times of the first toe length; outer metatarsal tubercle absent.

Skin finely granular above; upper eyelid with small tubercles; lateral head and flank smooth; chin and throat granular; chest, belly, and underside of thigh coarsely granular; supra-cloaca with a row of tubercles.

Coloration in life. Dorsal and lateral surfaces yellow, with brown pigments; the pigments, sometimes forming a large mark in occiput region and anterior part of dorsum; a dim, brown tripe underlined canthus rostralis; upper lip white in posterior; ventral surface immaculate white, margin of chin and underside of thigh with dark brown pigments; limbs with blurry cross-bars; iris golden with some clouds of smoky grey; pupil vertical, black (identification followed Taylor, 1962 and Stuart et al., 2006).

Sexual dimorphism. Males with inner vocal sacs.

Taxonomic remarks. The specimens differ from Taylor's (1962) description by having a ratio of ED/SNL 0.77—0.81 (versus eye longer than snout) and the absence of tarsal fold (versus lateral tarsal fold faint).

Distribution. *C. nongkhorensis* is a widespread species in Asia, from India, Myanmar, Thailand, Laos, Cambodia, Vietnam, and Malaysia (Frost, 2013). This is the first time *C. nongkhorensis* is known from Binh Thuan Province, at elevation of 102 m. It has been reported from Lao Cai, Gia Lai and Dong Nai provinces in Vietnam as well (Nguyen et al., 2009). This species could be met in the open, cultivated habitats.

***Feihyla palpebralis* (Smith, 1924)**

English name: Vietnamese Bubble-nest Frog

Vietnamese name: Nhai Cay Vietnam, Nhai Cay Mi

(Plate 6. I—K)

Examined specimens. DT0029, DT0030, DT0032 (males) & DT0028, DT0031 (females) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0273 (female) was collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 20 April 2010; DT0508 (male) was collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 21 June 2011; and DT0980 (females) was collected at 12°15326 N, 108°462475 E, alt. 2066 m, in BDNB NP, on 07 August 2011.

Diagnosis. Habitus slender; SVL up to 36.6 mm; skin rough dorsally and coarsely granular on belly; dorsum yellow to light brown with a large brown mark; lateral head with a large white patch; fingers webbed at base (after Smith, 1924 & Inger et al., 1999).

Morphological characters. Habitus slender; SVL 19.3—30.5 mm in males (n = 5), 29.5—37.5 mm in females (n = 3); head as long as wide; snout pointed in dorsal view, protruding in profile; nostril

closer to tip of snout than to eye; canthus rostralis sharp; loreal region concave and slopping; ED/SNL 0.63—0.86; IO/UEW 1.12—1.55; tympanum round, TD/ED 0.48, E-T 0.7; supratympanic fold distinct; vomerine teeth present; tongue notched behind, at level 0.13—0.20 times of its length, and free at rear for 0.39—0.47 times of its length; choanae small, partly concealed under upper jaw's margin.

Relative finger length: II < I < IV < III; fingers webbed at base, formula: $I_{2½-2½}II_{2½-3¾}II_{3-2¾}IV$; terminations of fingers and toes enlarged into round discs with peripheral grooves; subarticular tubercles on fingers and toes conspicuous; tibiotarsal articulation extending to eye or nearly to nostril; relative toe length: I < II < III < = V < IV; toes moderately webbed, formula: $I_{1½-2}II_{1-2}III1¾_{-2¾}IV_{2½-1}V$; inner metatarsal prominent and elongated.

Skin rough dorsally, with some tiny granules on head and front of dorsum; chin and throat smooth; chest, belly, and ventral surface of thigh coarsely granular.

Coloration in life. Dorsal surface of body and limbs dark yellow to brown, with a triangular patch on anterior part of head; a large, brown mark with lighter border, running from orbital region, bifid into two long, thin branches at level of tympanum and extending to middle of dorsum; lateral head yellowish brown; tympanum brown; lower part of temporal region covered by a whitish patch; ventral surface yellow or white; transverse cross-bars on limbs distinct (identification after Smith, 1924, Bourret, 1942, and Inger et al., 1999).

Sexual dimorphism. Nuptial pad present on dorsal and lateral surfaces of the first finger in males.

Taxonomic remarks. The specimens do not match with previous descriptions (Smith, 1924, Bourret, 1942, & Inger et al., 1999) in the following features: ratio E-T/TD 0.17—0.36 (versus E-T equal to TD in Smith's description, 1924); inner metatarsal tubercle half of the first toe length (versus inner metatarsal tubercle one-third the length of the inner toe in Smith's description, 1924); eye with

reddish brown iris and round, black pupil (not mentioned by Smith, 1924, Bourret, 1942, & Inger et al., 1999).

Distribution. *Feihyla palpebralis* was originally discovered from Langbian Peak, alt. 2000 m in Lam Dong Province, Vietnam by Smith (1924). Occurrences of this species have been reported from Lam Dong, Gia Lai, and Vinh Phuc provinces of Vietnam and China, at elevations between 900−2000 m (Smith, 1924, Inger et al., 1999, Nguyen et al., 2009 & Frost, 2013).

***Kurixalus baliogaster* (Inger, Orlov, and Darevsky, 1999)**

English name: Belly Spotted Frog

Vietnamese name: Ech Cay Bung Dom

(Plate 6. M−O)

Examined specimens. DT0039 (male) was collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0150, DT0155, DT0156 & DT0161 (males) were collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 19 March 2010; DT0431 (male) was collected at 12°1735 N, 108°7 E, alt. 1494 m, in BDNB NP, on 01 June 2010.

Diagnosis. SVL 33−41.4 mm; ventral surface of body white with dark brown or black spots; webbing reaching to proximal subarticular tubercle on the third finger; dermal fringes along outside of limbs absent; appendages around vent absent (after Inger et al., 1999).

Morphological characters. Habitus slender; size medium, SVL 22.8−36.9 mm in males (n = 6); head as long as wide; snout pointed in dorsal view, slopping in lateral view; nostril round, closer to tip of the snout than to eye; canthus rostralis unclear; loreal region oblique; eye prominent, ED/SNL 0.83; IO/UEW 0.93−1.21; tympanum round, TD/ED 0.31−0.52; supratympanic fold distinct; vomerine teeth in two oblique rows.

Relative of finger length: I < II < IV < III; tips of fingers enlarged into round, flat discs, bearing peripheral grooves; disc on the third finger smaller than tympanum diameter; fingers webbed at base, formula: I–II2½–3¾III3½–2¾IV; subarticular tubercles on fingers round, prominent; three oval palmar tubercles; discs on toes smaller than those on fingers; relation of toe length: III < III < V < IV; toe webbing formula: I1¼–2II1¼–2III1¼–2½IV2½–1V; inner metatarsal tubercle long and flat; outer metatarsal tubercle absent.

Dorsal skin with tiny tubercles; upper eyelid without tubercles; flank smooth; chest and belly coarsely granular; appendages around vent absent.

Coloration in life. Dorsal surface reddish brown, with a small irregular dark brown marking in occiput and shoulder regions; region surround vent white; loreal dark brown with a large, white patch, from below the eye to front of tympanum; upper part of flank reddish beige, lower part light fleshy, with light brown dots in irregular size and shape in axilla region, white dots at groin; ventral surface white with dark brown dots; dorsal limbs light brown, with dark brown cross-bars; elbow and heel covered by large, reddish white patches; ventral, anterior and posterior surfaces of thigh, tibia, and foot yellowish orange.

Sexual dimorphism. Males with white nuptial pads on dorsal and lateral aspects of the thumbs.

Taxonomic remarks. The specimens differ from the original description of Inger et al. (1999) in the following characters: throat coarsely granular (versus the throat smooth); tibiotarsal articulation reaching to tip of snout; heels overlapped when legs are folded at right angles to body; iris golden brown with tiny black reticulation; pupil round, black with a light reddish brown outline; scleral arc light reddish brown, staining with black (not mentioned in Inger's description).

Distribution. *Kurixalus baliogaster* has been known only from the type locality and adjacent areas including Lam Dong Province of Vietnam and Laos, at elevations of 700—1000 m (Nguyen et al.,

2009). During our surveys, this species was found at elevations up to 1500 m, in Lam Dong Province.

***Polypedates megacephalus* Hallowell, 1861**

English names: Hong Kong Whipping Frog, Spot-legged Treefrog, Hour-glass-marked Treefrog

Vietnamese name: Ech Cay Dau To

(Plate 7. B—C)

Examined specimens. DT0379 (male) & DT0377—78 (females) were collected near to fish farm in BDNB NP, in March 2010; DT0991 (female) was collected at 12°134272 N, 108°479302 E, alt. 1597 m, in BDNB NP, on 08 August 2011; DT0554 (male) and DT0534 (female) were collected from 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 5—6 June 2011; DT1047 was collected from 12°461853 N, 108°417369 E, alt. 1042 m, in CYS NP, on 16 October 2011; and DT0435 (female) was collected at 12°015165 N, 108°727121 E, alt. 900 m, in PB NP, on 24 September 2011. Photographs of this species collected from SLSM, in August 2011.

Diagnosis. Size medium to large; dorsal skin smooth; skin of head co-ossified to skull; Size of body medium to large; dorsal skin smooth; an hour-glass mark present in region between occiput and shoulder; dorsal stripes absent; discs on the third fingers narrower than tympanum diameter; fingers free of webbing; and vocal sac present in males (after Taylor, 1962; Liem, 1970; Inger et al., 1999; Kuraishi et al., 2013)

Morphological characters. Size medium, SVL 33.0—56 mm in males (n = 2), 50.6—78.0 mm in females (n = 6); head as long as wide; snout pointed in dorsal view, beyond lower jaw in profile; nostril closer to tip of snout than to eye; canthus rostralis distinct; loreal region clearly concave; ED/SNL 0.68; IO/UEW 1.31—1.80; tympanum very distinct, E-T/TD 0.25—0.44; supratympanic fold distinct; vomerine teeth in two oblique ridges, length of the ridges longer than distance between them; tongue notched and free behind.

Limbs slender; relative finger length: I < II < IV < III; fingers free of webbing, terminating with round and flat discs that having circummarginal grooves; subarticular tubercles on fingers round, well developed; inner metacarpal tubercle flat, 0.50—0.70 times of the first finger length; outer metacarpal tubercle small; tibiotarsal articulation reaching to between eye and nostril or beyond to tip of snout; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes smaller than those on fingers; toes webbing well developed, formula: $I_{1½-2}II_{1-2}III_{1-3}IV_{2-1}V$; inner metatarsal tubercle small; outer metatarsal tubercle small, round, and flat; tarsal fold absent.

Skin of dorsal head involved with skull; dorsal skin of body and limbs smooth; lower part of flank, belly and ventral surface of thigh coarsely granular.

Coloration in life. Dorsal surface yellow to brown or dark green or grey; occiput and anterior part of dorsum bearing a large dark brown mark, in ")(" shape; dorsal surfaces limbs with well defined, dark brown transverse cross-bars; lateral head dark brown or grey; edge of upper lip white; supratympanic fold underlined by a dark brown streak, extending to shoulder or anterior part of flank; posterior part of flank with or without light brown spots; ventral surface white with small brown or light grey pigments; posterior part of thigh dark brown marbling with white spots (after Taylor, 1962; Liem, 1970; Inger et al., 1999; Kuraishi et al., 2013).

Sexual dimorphism. A gular pouch present in males.

Taxonomic remarks. The specimens differ from previous descriptions by having a tongue which free at rear for nearly half of its length (versus tongue free for two fifths of its length in Taylor's description, 1962); some specimens (DT0377—8, DT0435, & DT991) from the Langbian Plateau have dorsum with two pairs of longitudinal brown lines and disc of the third finger 0.2—0.4 times of tympanum diameter (versus the "*Polypedates* nonstripe" form has a disc of the third finger narrower than tympanum diameter in the description of Inger et al., 1999).

Distribution. This species has wide distribution in Asia including India, Myanmar, Taiwan, Japan, Lao, Thailand and northern Vietnam (Nguyen et al., 2009, Frost, 2013). This is the first time *P. megacephalus* is recorded from the Langbian Plateau, southern Vietnam.

Reproductive biology (Plate 12). This species often chooses lentic water bodies such as ponds, swamps, channels close to paths in forests or in human habitations for breeding sites. One or many males conducted amplexus activity with a female. This species has axillary amplexus pattern. The eggs were laid in masses of foam that were floating on water surface or contacted with vegetation along the edges of the water bodies.

***Polypedates* cf. *mutus* (Smith, 1940)**

English names: Burma Whipping Frog

Vietnamese name: Ech Cay Mi-an-ma

(Plate 7. A)

Photographs were taken from BDNB NP, near to 12°18613N, 108°714E, and alt. 1553 m, on 17 Mark 2010.

Diagnosis. Size of body medium to large; dorsal skin smooth; four stripes present on dorsum; discs on the third fingers as wide as tympanum diameter; fingers free of webbing; and vocal sac absent in male (after Smith, 1940; Inger et al., 1999; Kuraishi et al., 2013).

Morphological characters. Snout pointed and protruding in profile; nostril closer to tip of snout than to eye; canthus rostralis distinct; loreal region clearly concave; tympanum round, supratympanic fold prominent.

Limbs slender; fingers free of webbing, terminating with round and flat discs; disc on the third finger as broad as tympanum diameter.

Skin of entire body and limbs smooth but lower part of flank, belly and ventral part of thigh coarsely granular.

Coloration in life. Dorsal surface dark yellow, with dark brown stripes; limbs with well defined, dark brown transverse cross-bars; side of head brown; edge of upper lip white; supratympanic fold underlined by a dark brown streak, extending to shoulder or anterior part of flank; posterior part of flank with brown dots; ventral surface immaculate white (identification after Smith, 1940; Inger et al., 1999; Kuraishi et al., 2013).

Distribution. This species has a range of distribution in Myanmar, China, Vietnam, Laos, and Thailand. In Vietnam, this species occurred in north and central areas, from border of China to Kon Tum Province (Inger et al., 1999; Orlov et al., 2001; Nguyen et al., 2009, Kuraishi et al., 2012 and Frost, 2013). This is the first report of this species' occurrences in the Langbian Plateau, south of Vietnam.

***Raorchestes gryllus* (Smith, 1924)**

English name: Langbian Bubble-nest Frog

Vietnamese name: Nhai Cay Langbian

(Plate 7. D—F & Plate 13)

Examined specimens. DT0004 (male) & DT0002 (female) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0076, DT0079—81 (females) were collected at 12°094939 N, 108°660495 E, alt. 2027 m, in BDNB NP, on 21 March 2010; DT0089, DT0093, DT0098, DT0102, DT0105, DT0108, DT0144 (males) & DT0097, DT0100, DT0106, DT0110—11, DT0132, DT0139—40 (females) were collected at 12°096156 N, 108°660697 E, alt. 2004 m, in BDNB NP, on 22 march 2010; DT0185 (male) & DT0182 (female) were collected at 12°095479 N, 108°660901 E, alt. 1993 m, in BDNB NP, on 23 March 2010; DT0206 (male) & DT0215, DT0229 (females) were collected at 12°214 N, 108°697775 E, alt. 1271 m, in BDNB NP, on 27 March 2010; DT0232, DT0242, DT0246 (males) & DT0241, DT0245 (females) were collected at 12°212795 N, 108°699444 E, alt. 1399 m, in BDNB NP, on 28 March 2010; DT0297 (male) & DT0299 (female) were collected at 12°186132 N,

108°714042 E, alt. 1553 m, in BDNB NP, on 24 April 2010; DT0309, DT0311—12 (males), DT0316, DT0318 (females) were collected at 12°194821 N, 108°712284 E, alt. 1908 m, in BDNB NP, on 24 June 2010; DT0349 (female) was collected at in BDNB NP, on 27 April 2010; DT0523 (male) was collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 24 June 2011; DT0984 (male) was collected at 12°134646 N, 108°478829 E, alt. 1660 m, in BDNB NP, on 06 August 2011; DT0604, ST0606 (males) were collected at 12°409862 N, 108°398236 E, alt. 1642 m, in CYS NP, on 29 May 2010; DT0595, DT0602 (males) were collected at 12°409862 N, 108°398236 E, alt. 1642 m, in CYS NP, on 30 May 2010; DT0561 (male) was collected at 12°451146 N, 108°454748 E, alt. 880 m, in CYS NP, on 03 June 2011; DT0889, DT0931—32 (males) were collected near to 12°498845 N, 108°414734 E, alt. 1016 m, in CYS NP, on 14 October 2010; DT0939 (male) was collected at 11°874513 N, 108°020474 E, alt. 1261 m, in CYS NP, on 28 September 2011; DT0747 (male) was collected at was collected at in TD NR, on 24 June 2010 in TD NR, on 17 July 2010; DT0887 (female) was collected at 11°874513 N, 108°020474 E, alt. 1261 m, in TD NR, on 23 December 2010; DT0460—63 (males) were collected at 11°819028 N, 108°044821 E, alt. 1150 m, in TD NR, on 07 March 2011; DT0944, DT0949, DT0951, DT0953 (males) & DT0945 (female) were collected at 11°868358 N, 108°026506 E, alt. 1514 m, in TD NR, on 24 July 2011.

Diagnosis. Size small to medium (SVL up to 28 mm in males, 34 mm in females); vomerine teeth absent; choanae visible; dorsal skin with tubercles, ventral skin coarsely granular; dermal fringes along outer edges of fore and hind limbs well developed; discs of digits bearing circummarginal grooves; fingers free of webbing; toes webbed (followed Orlov et al., 2012).

Morphological characters. The collected specimens agree with descriptions of *Raorchestes gryllus* of Smith (1924) and Orlov et al. (2012) by having the following features: size small, SVL 20.5—28.8 mm in males (n = 37), 23.6—36.7 mm in females (n = 24); head as long as wide; snout pointed in dorsal view; nostril lateral, round, midway between tip of snout and eye; canthus rostralis distinct; eye with ED/SNL 0.82; IO/UEW 0.81—1.52; tympanum visible,

rounded, smaller than half of eye diameter; supratympanic fold distinct; vomerine teeth absent; choanae small, round, uncovered by upper jaw's margin.

Relation of finger length: I < II < IV < III; tips of fingers with enlarged round discs, with peripheral grooves; disc of the third finger smaller than or equal to tympanum diameter; subarticular tubercles on fingers rounded and prominent; fingers webbed at base; series of tubercles along outer margins of the fourth finger and hand present; tibiotarsal articulation reaching to eye; relation of toe length: I < II < III < V < IV; tips of toes and subarticular tubercles on toes similar to those on fingers but smaller in sizes; inner and outer metatarsal tubercles present; toe webbing developed, formula: $I_{2-2}II_{1-2½}III_{1¾-2½}IV_{2-1½}V$; outer margins of the fifth toe, foot, and tarsus with small tubercles.

Skin covered with tiny tubercles dorsally; throat finely granular; belly and ventral surface of thigh coarsely granular; small tubercles on heel present.

Coloration in life. Color pattern varies depending on sexual and individual. In males, dorsal surface light brown staining with reddish brown or with bright green marbling on head, dorsum and limbs; a bright green triangle patch, on anterior part of upper eyelid and snout, sometimes this patch combining with the posterior bright green marbling or just staining and mixing with the background as some small green scraps; a dark brown lateral dorsal long mark, in ")(" or "M" shape, from rear of eye to groin, present or absent; color pattern of upper part of flank similar to that on dorsum, lower part fleshy, with irregular dark brown spots or dark brown oblique stripes; venter white; upper parts of limbs with dark brown transverse bars. Female uniform green above, flank white with or without dark grey stripe between lower and upper parts, ventral surface white.

Sexual dimorphism. Males relatively smaller than females and having a wide variation in dorsal color patterns (plate 13). Males also have a gular pouch and nuptial pad on dorsal and lateral surfaces of thumb.

Taxonomic remarks. The specimens differ from previous descriptions by having the following characters: iris light golden with brown or reddish mottles posteriorly, pupil horizontal oval and black (not mentioned by Smith, 1924 and Orlov et al., 2012).

Distribution. This species has been known from Lao Cai, Tuyen Quang, Cao Bang, Lang Son, Vinh Phuc, Thanh Hoa, Dak Lak, and Lam Dong, Vietnam (Nguyen et al., 2009 and Orlov et al., 2012). In Langbian Plateau, this species has been recorded in Lam Dong, Dak Nong, Dak Lak, and Ninh Thuan provinces, at elevations of 880—2027 m.

Reproductive biology (Plate 12). A pair in amplexus of this small tree-frog was met on a leaf of a small tree, about 1.2 m above the ground. Males of this species often sat together for chorus activity after the sunset.

***Rhacophorus annamensis* Smith, 1924**

English names: Annam Flying Frog, Daban Flying Frog

Vietnamese name: Ech Cay Trung Bo

(Plate 7. G—I)

Examined specimens. DT0625 (male) was collected at 12°211188 N, 108°444591 E, 818 m elev., in BDNB NP, on 10 June 2010; DT0581—82, DT0584—586 (males) & DT0583 (female) were collected at 12°42366 N, 108°350285 E, 864 m elev., in CYS NP, on 01 June 2011; DT0541—43 (males) & DT0540, DT0571 (females) were collected at 12°451146 N, 108°454748 E, 880 m elev., in CYS NP, on 04 June 2011; DT0927 (female) was collected at 12°079296 N, 108°734607 E, 782 m elev., in PB NP, on 29 Sep 2011; DT0704, DT0712, DT0715, DT0729—30 (males) & DT0703 (female) were collected at 11°835015 N, 108°00817 E, 1262 m elev., in TD NR, on 13 Jul 2010. DT0496, DT0497—501 (males) & DT0487 (female) were collected at 11°8588 N, 107°999 E, 859—910 m elev., in TD NR, on 19 April 2011. Photographs were taken in SLSM, in August 2011 and in PB NP, on 17 August 2012.

Diagnosis. Size large; dorsum yellow brown to dark brown or pinkish, with or without large dark brown dots; skin smooth with scattered tiny granules above; belly coarsely granular; fingers and toes fully webbed.

Morphological characters. SVL 41.7—71.8 mm in males (n = 23), 76.2—84.3 mm in females (n = 7); snout pointed in dorsal view, slopped in profile; tip of snout beyond to mouth; nostril lateral, round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region oblique and concave; IO/EUW 0.94—1.66; tympanum round, with elevated rim, TD/ED 0.43—0.61, E-T/TD 0.21—0.57; supratympanic fold distinct; vomerine teeth present, in two oblique rows.

Relative finger length: I < II < IV < III; tips of fingers with enlarged discs, with circummarginal grooves; discs wider than long; disc of the third finger subequal to tympanum diameter; fingers fully webbed, formula: $I_{2-1}II_{0-0}III_{0-0}IV$; subarticular tubercles on fingers round, prominent; tibiotarsal articulation reaching to eye or midway between eye and nostril; heels overlapped when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes similar to those on fingers but smaller in sizes; toes fully webbed: $I_{0-0}II_{0-0}III_{0-0}IV_{0-0}V$; inner metatarsal tubercle prominent, elongated, 0.36—0.60 times in length of the first toe; outer metatarsal tubercle absent.

Skin smooth with scattered tiny granules dorsally and laterally; skin on upper part of flank smooth with fine granules, lower part granular; chin, throat, and chest smooth; belly and ventral surface of thigh coarsely granular; dermal fringes along outer edges of lower arm, the first and fourth fingers distinct; cloaca with a dermal flap above and tubercles below; tubercles on heel present.

Coloration in life. Dorsal surface of head and body yellowish brown to dark brown or pink, with or without large dark brown dots; occiput with two dark brown bars; lateral head brown; tympanum dark brown; upper jaw with dark brown patches; upper part of flank yellow marbling with brown, lower part white with black reticulation in axilla and groin regions; throat and chest white,

pigmented with some dark brown speckles; chin and belly white or yellowish white; limbs with clear dark brown cross-bars; inner part of lower arm sometimes yellowish-orange; ventral surface of hand pink; anterior surface of thigh greyish; ventral surface of foot grey or orange; discs of fingers and toes dark brown dorsally and grey ventrally; dorsal and ventral surfaces of webbings brown or dark grey; iris bronze with brown reticulation, outlined by a thin, black ring, outer membrane white; pupil horizontal oval and black (followed Smith, 1924, Inger et al., 1999, and Stuart et al., 2006).

Sexual dimorphism. Males much smaller than females; nuptial pad developing on dorsal and lateral parts of thumb in the males.

Distribution. This tree-frog was found from many sites of the protected areas within the Langbian Plateau and neighboring areas at elevations between 200 and 1262 m (Smith, 1924, Inger et al., 1999, and Frost, 2013). This species has been known from Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Dak Lak, Lam Dong, and Ninh Thuan provinces in Vietnam and Mondulkiri Province of Cambodia (Nguyen et al., 2009; Stuart et al., 2006). These are new records of this species from Dak Nong and Binh Thuan provinces.

Reproductive biology (Plate 12). Calling frogs were found between May and July. The calling frogs often sat on branches of trees that were hanging over a pond or shallow water in forests, about 1.5−2.5 m above the ground. The ponds and shallow water, in general, were about 10−100 m^2, 0.2−0.4 m in depth, with muddy bottoms that had many leaves and fallen trees decay. Five or six males were gathering together near to a pond for calling. Two pairs in axillary amplexus performed on a tree, about 1.5 m above the ground, in an evergreen forest of TD NR, were encountered in July 2010. Two couples of this species in amplexus in ponds and another amplexus couple on a trunk were found in the evergreen forest of CYS NP, in May and June 2011. One female (DT0703), collected in July, was in gravid condition, bearing white eggs, 2 mm in diameter.

***Rhacophorus calcaneus* Smith, 1924**

English name: Vietnam Flying Frog

Vietnamese name: Ech Cay Cua

(Plate 8. A—G)

Examined specimens. DT0006 (female) was collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 18 March 2010; DT0208—09, DT0210—11 (males) were collected at 12°214 N, 108°697775 E, alt. 1271 m, in BDNB NP, on 27 March 2010; DT0267, DT0278 (males) were collected at 12°182969 N, 108°67888 E, alt. 1494 m, in BDNB NP, on 27 March 2010; DT0294, DT0340—42, DT0384—85, DT0430 (males) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 27 April 2010; DT0502—06 (males) & DT0524 (female) were collected at 12°175544 N, 108°700715 E, alt. 1515 m, in BDNB NP, on 21 June 2011; DT0589, DT0591—94, DT0607—08 (males) were collected at 12°40773 N, 108°394624 E, alt. 1617 m, in CYS NP, on 30 May 2011; and DT0974 (male) were collected at 12°40773 N, 108°394624 E, alt. 1617 m, in TD NR, on 26 July 2011.

Diagnosis. SVL up to 45.8 in males, 60.2 mm in females; dorsum pale green to dark green or dark brown with many small, white or yellow spots; two black patches present on axilla and groin; fingers and toes well webbed; dermal fringes along outer margins of the fourth finger, lower arm, fifth toe, and foot distinct; projection on heel pointed and long (after Tran et al., 2011; Orlov et al. 2012).

Morphological characters. Size medium to large, SVL 35.1—45.8 mm in males (n = 26), 53.6—53.9 mm in females (n = 2); head as long as wide; snout pointed in dorsal view, protruding in profile; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; ED/SNL 0.69—1.05; interorbital region flat, IO/UEW 0.93—1.42; tympanum round, TD/ED 0.31—0.55, E-T/TD 0.27—0.64; supratympanic fold distinct; choanae small, round; vomerine teeth grouped into two oblique rows, the rows closer to choanae than to each other; tongue bifid at rear, at level 0.14—0.25 times of its length and free posteriorly for 0.25—0.53 times of its length.

Fore limbs slender; relative finger length: I < II < IV < III; tips of fingers flat, enlarged into round discs with circummarginal grooves; disc of the third finger as large as or slightly larger than tympanum diameter; fingers webbed, formula: $I_{2-2}II_{1½(2)-2½(¾)}III_{(1¾)2-(1¾)2}IV$; dermal fringes along outer margins of the fourth finger and lower arm present; subarticular tubercles on fingers round, prominent and conspicuous; tibiotarsal articulation extending to eye or between eye and tip of snout; heels overlapped when legs held at right angles to body; relative toe length: I < II < V < III < IV; discs of toes round with circummarginal grooves; discs of toes smaller than those of fingers; toes broadly webbed, formula: $I_{1-2(2¼)}II_{1½-2}III_{1-1½(2)}IV_{1½(2)-1½}V$; dermal fringes along outer margins of the fifth toe and foot less developed than those on the fourth finger and lower arm; tibiotarsal articulation with a long, pointed projection; inner metatarsal tubercle flat, oval, 0.34—0.62 times of the first toe length; outer metatarsal tubercle absent.

Skin smooth above; upper part of flank smooth, lower part granular; throat and chest granular; belly and ventral surface of thigh coarsely granular; posterior cloacal appendix present.

Coloration in life. Dorsum pale green, olive or reddish brown to dark greenish brown, with many small white or yellow spots; a pair of yellow dorsolateral stripes, stretching from posterior corners of eyes to groins; another medium yellow stripe, extending from behind the middle of dorsum towards cloaca, present or absent; a triangle on the dorsal surface of head formed by stripes along edge of snout and a light stripe between eyes distinct or indistinct; a thin, light stripe running along canthus rostralis, from tip of snout to middle of the eye; flank yellow to orange; ventral surface bright yellow without small spot; axilla, groin, anterior surfaces of upper arm and thigh, and posterior surfaces of thigh and tibia usually with large, black patches, various in shapes and sizes; these patches sometimes surrounded by bright blue color and more obvious in females; upper surfaces of limbs resembling the dorsum; anterior and posterior surfaces of limbs yellow to orange; webbings on fingers and toes yellow or orange dorsally, sometimes with black pattern at base; discs of fingers and toes yellow to orange;

posterior cloacal appendix white; projection at the heel yellow or orange; pupil horizontal, black; iris brown, fading into red-orange at the upper and lower parts, surrounded by an inner black and outer blue circle (identification followed Smith, 1924; Orlov et al., 2008; Tran et al., 2011).

Sexual dimorphism. Females larger than males; ground color of dorsum usually green. In female, the bright bluish patterns on axilla, groin and front of the forearm are more obvious and extending to the middle of flank, covered nearly the whole anterior surface of the forearm. In addition, the posterior surfaces of thigh and tibia of the female are covered with large black, elongated patches. Internal vocal pouch and nuptial pad distinct in male; nuptial pad present on lateral and dorsal aspects of the first finger, from finger base to proximal end of penultimate phalanx; nuptial pad longer than length of the first finger.

Taxonomic remarks. This species was discovered from the Langbian Plateau by Smith (1924). This rhacophorid was well known with dorsal coloration of yellow brown or red brown and pointed projection on heels. Another form of this species which has green color on dorsum was introduced as a different species, *Rhacophorus chuyangsinensis* (Orlov et al., 2008) and reassigned as junior synonym of *R. calcaneus* (Orlov et al., 2012).

Distribution. Occurrences of this species have been known from the type locality of Langbian Peak, Lam Dong Province and adjacent regions of Dak Lak and Khanh Hoa provinces of Vietnam, at elevations between 1300 and 2000 m (Smith, 1924; Orlov et al., 2008; Tran et al., 2011; Frost, 2013). This is a new provincial record of this species from Dak Nong Province.

***Rhacophorus robertingeri* Orlov, Poyarkov, Vassilieva, Ananjeva,**

Nguyen, Nguyen, Geissler, 2012

English name: Robert Tree Frog

Vietnamese name: Ech Cay Ro-ber-ti

(Plate 8. H—I)

Examined specimens. M01 & M02 (juveniles) were collected at 12°186132 N, 108°714042 E, alt. 1553 m, in BDNB NP, on 01 August 2011; DT0680 &DT0681 (females) were collected at 11°835015 N, 108°00817 E, alt. 967 m, in TD NR, on 22 December 2010.

Diagnosis. Habitus stocky; size large, SVL up to 57.68 mm; snout pointed, slopping and protruding in lateral view; dorsum generally yellow to reddish brown, with white and dark brown spots; fingers and toes webbed; dermal fringes along outer edges of the fourth finger and forearm, fifth toe, foot and tarsus present; projection on heel pointed, long; projection above vent distinct (after Orlov et al., 2012).

Morphological characters. Specimens resemble description of *Rhacophorus robertingeri* by Orlov et al. (2012) in the following contributes: SVL 29.5—38.2 mm in females (n = 4); head as long as wide; snout pointed in dorsal view, protruding in lateral view, snout half in length of head; canthus rostralis distinct; loreal region oblique and concave; eye large, ED/SNL 0.74—0.95, IO/UEW 1.00—1.46; tympanum round, TD/ED 0.32—0.49, E-T/TD 0.37—0.48; supratympanic fold distinct; vomerine teeth present, in oblique rows, the rows shorter than distance between them; choanae round, one-third concealed by edge of upper jaw; tongue free behind for a half of its length, notched posteriorly, at level of 0.18—0.21 times of its length.

Limbs slender; relative finger length: I < II < IV < III; tips of fingers and toes with round discs, bearing circummarginal grooves; width of the third finger disc subequal to tympanum diameter; fingers webbed, formula: $I_{2-2}II_{1½-2½}III_{2-1½}IV$; subarticular tubercles on fingers round and conspicuous; palmar tubercle flat; heels overlapped when legs held at right angles to body; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes smaller than those on fingers; toes fully webbed; inner metatarsal tubercle oval, prominent, its length half of the first toe length; outer metatarsal tubercle absent.

Skin on dorsal and lateral head smooth; chin, throat, and chest smooth; belly and ventral of thigh coarsely granular; lateral dermal fringes along outside edges of the first and fifth toes, foot, and tarsus developed; cloaca with a dermal flap above.

Coloration in life. Dorsal and lateral head pinkish brown, with many black small spots, forming three cross-rows on head: the first row at middle between nostril and anterior corner of eye, the second in occiput region, and the third dimmer and fewer in number of spots, at level of above tympanum; dorsum pinkish brown, covered by scattered, small, black spots and some larger white dots; flank dark grey marbling with white; chin and throat white, reticulated in dark brown; belly and ventral surface of thigh yellow; upper parts of limbs with indistinct cross-bars; lateral and ventral surfaces of limbs orange or yellow with some white spots; discs of fingers and toes yellow or brown; webbings on fingers and toes orange and yellow, with dark grey margins; dermal ridges along outer margins of hand, lower arm, foot, and tarsus white; iris yellowish brown with dark brown reticulation, edged in black; pupil horizontal oval and black.

Taxonomic remarks. The specimens differ from the original decription (Orlov et al., 2012) by having toe webbing: $I_{0-1½}II_{0-1}III_{1-2¼}IV_{½-1}V$ (versus the formula: I(0.5)IIi(0.5)e(0)IIIi(0)e(0) IVi(0.5)e(0.5)V(0) that followed Glaw & Vences, 1994 and equivalent to $I_{1½-1½}II_{1-1}III_{1-1½}IV1_{½-1}V$ in formula of Guayasamin et al., 2006).

Distribution. Distribution of *R. robertingeri* in Vietnam is uncertain because many records were based on misidentification (Orlov et al., 2012). This species has been known from central Vietnam, including Quang Nam, Da Nang, Quang Ngai, Thua Thien - Hue, Gia Lai, and Kon Tum provinces, at elevations of 400—1700 m (Tran et al., 2010; Orlov et al., 2012 and Frost, 2013). This is a new provincial record of this species from Dak Nong Province.

Reproductive biology (Plate 12). Activities of calling or mating of this species were not encountered but two juvenile specimens were collected on 01 August 2011 from an evergreen forest, in BDNB NP, at elevation of 1553 m.

***Rhacophorus vampyrus* Rowley, Le, Tran, Stuart, and Hoang, 2010**

English name: Vampire Tree Frog

Vietnamese name: Ech Cay Ma Ca Rong

(Plate 7. J—L)

Examined specimens. UNS00105 (female) was collected 12°1736 N, 108°6987 E, alt. 1470 m, in BDNB NP, on 18 March 2010; ZFMK 91076 (male) was collected at 12°0096 N, 108°6607 E, alt. 2004 m, in BDNB NP, on 23 March 2010; DT0973 (female) was collected at 11°857053 N, 108°037075 E, alt. 1935 m, in TD NR, on 26 July 2011. Photographs taken in June and August 2011.

Diagnosis. Dorsum pale tan to brick red; throat, chest and belly white; flank and anterior and posterior surface of thighs mostly black; webbings between fingers and toes grey to black; and pointed projection on heels present (after Rowley et al., 2010b).

Morphological characters. Habitus slender; SVL 43.3 mm in male (n = 1), 47.5—53.4 mm in females (n = 2); head as long as wide; snout truncated in dorsal view, shortened and just protruding in lateral view; tip of snout pointed; nostril vertical oval, closer to tip of snout than to eye; canthus rostralis distinct; loreal region oblique and concave; ED/SNL 0.84; IO/UEW 1.07—1.13; tympanum round, TD/ED 0.37—0.60, E-T/TD 1.35—2.0; supratympanic fold visible; vomerine teeth grouped into oblique rows; choanae oval, partly hidden by upper jaw's edge; tongue free and notched behind.

Limbs slender; relation of finger length: I < II < IV < III; tips of fingers enlarged into round discs with circummarginal grooves; width of the third finger disc larger than that of tympanum; all fingers webbed, formula: $I_{2-2}II_{1-2}III_{2-1}IV$; subarticular tubercles on fingers round and conspicuous; palmar tubercle absent; tibiotarsal articulation reaching to eye; relation of toe length: I < II < III < V < IV; discs of toes smaller than those of fingers; toe webbing formula: $I_{1-2}II_{1-2}III_{1-2}V_{2-1}V$; subarticular tubercles on toes round; inner metatarsal tubercle low, oval; outer metatarsal tubercle and tarsal fold absent; projection on heel present.

Skin on head, dorsum, upper part of flank, chin, throat, and chest smooth; lower part of flank, belly, and ventral surface of thigh coarsely granular; dermal fringes along outer margins of the first and fourth fingers, lower arm, the first and fifth toes, foot, and tarsus present; dermal ridge above vent distinct.

Coloration in life. Dorsal surface of body, limbs, and upper part of flank copper-brown or pale yellow-brown with dark brown mottles and sparse, small, white and dark brown spots along dorsum; lower part of flank white marbling with a black patch at middle, two other large, black patches present on axilla and groin; ventral surface white; dark brown transverse cross-bars on limbs distinct; anterior and posterior surfaces of forearm and thigh black; dorsal surfaces of distal parts of fingers and toes grey or dark grey; webbing grey to black (identification followed Rowley et al., 2010b).

Sexual dimorphism. Males with a pair of oval vocal sac openings at base of jaw.

Distribution. *Rhacophorus vampyrus* was recently discovered from Lam Dong and Dak Nong provinces of Vietnam at elevations from 1470 to 2004 m (Rowley et al., 2010b).

Reproductive biology (Plate 12). Activities of calling and mating of this tree-frog were unknown during the surveys, but foam nests and tadpoles of this species were met between June and July of the years 2010 and 2011, in the same tree-holes in the evergreen forest of BDNB NP. Eggs were deposited in foam nests in small tree-holes, 0.3−1.2 m above the ground, away from the streams (at least 2 m). Openings of the holes were usually covered with moss. An adult of this species was seen adjacent to a tree-hole.

Theloderma asperum (Boulenger, 1886)

English names: Hill Garden Bug-eyed Frog, Warty Tree Frog, and Rough-skinned Whistling Tree Frog

Vietnamese name: Ech Cay San A-x-po

(Plate 8. J & K)

Examined specimens. DT0207 (male) was collected at 12°214 N, 108°697775 E, alt. 1271 m, in BDNB NP, on 27 March 2010.

Diagnosis. Size small; skin rough with tubercles; vomerine teeth absent; fingers free; dorsum white and dark brown; iris reddish brown (after Rowley et al., 2011a).

Morphological characters. The specimen resembles descriptions of *Theloderma asperum* (Taylor, 1962; Stuart et al., 2006 and Rowley et al., 2011a) in the following characters: size small, SVL 26.1 mm (male, n = 1); head longer than wide; snout round in dorsal view, round and protruding in profile; nostril round, closer to tip of snout than to eye; canthus rostralis blunt; loreal region oblique; ED/SNL 0.67; IO/UEW 1.55; tympanum round, TD/ED 0.72, E-T/TD 0.27; supratympanic fold absent; vomerine teeth absent; choanae round, small; tongue notched and free behind for 0.2 times of its length.

Fore limbs slender; relative finger length: I < II < IV < III; fingers free of webbing; tips of fingers enlarged into discs, bearing circummarginal grooves; width of the third finger's disc approximately half of tympanum diameter; subarticular tubercles on fingers round and well developed; hand with one inner and two outer metacarpal tubercles; tibiotarsal articulation touching the eye; heels overlapped when legs are folded at right angles to body; discs and subarticular tubercles on toes similar to those on fingers but smaller in sizes; toe webbing well developed, formula: $I_{1-2}II_{1-2½}III_{1-2½}IV_{2½-1}V$; inner metatarsal tubercle distinct and long, half of the first toe length; outer metatarsal and tarsal fold absent.

Skin on dorsal surface of body and limbs warty with large, pointed tubercles; tubercles on middle dorsum, more prominent than those in surround region, grouped in short tubercle ridge; lateral head and upper part of flank with smaller tubercles, lower part of flank smooth; chin and throat smooth; belly and ventral surfaces of limbs coarsely granular.

Coloration in life. Dorsal surface white, masked by large dark brown patches: a thin, unclear dark brown bar on dorsal of snout, a depressed margin triangular in between occiput and shoulder

regions, another larger triangular patch on posterior part of dorsum, between groins and forward to middle of dorsum; lateral head with a pair of patches, from front of eye, through temporal region, connected with dark brown regions of upper arm and flank; temporal region with a white line, running from upper part of tympanum downward to maxillary angle; upper part of flank dark brown, lower part light brown; rump yellowish; ventral surface dark brown, chin, throat, chest with two white patches, in irregular shapes, posterior part of belly and ventral surface of thigh with white reticulations; limbs brown with dark brown or black cross-bars, tibia and tarsus with a broad white band; tubercles and granules white; iris reddish with brown reticulation; pupil black, round.

Sexual dimorphism. Males with nuptial pads on half of the first fingers.

Taxonomic remarks. The specimen differs from previous descriptions as follows: choanae round, small, partly hidden under maxillary edge (versus choanae completely exposed in Taylor's description, 1962).

Distribution. *Theloderma asperum* has been reported from India, China, Myanmar, Laos, Thailand, Cambodia, Malaysia, at elevations approximate 250—1000 m (Stuart et al., 2006 and Frost, 2013). Its existences have been known from Lai Chau, Lao Cai, Ha Giang, Tuyen Quang, Cao Bang, Phu Tho, Vinh Phuc, Hai Duong, Ninh Binh, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Lam Dong, Dong Nai provinces of Vietnam (Nguyen et al., 2009). In Langbian Plateau, this species was recorded at elevations up to 1300 m.

***Theloderma bambusicolum* Orlov, Poyarkov, Vassilieva, Ananjeva,**

Nguyen, Nguyen & Geissler, 2012

English name: Bamboo Moss Frog

Vietnamese name: Ech Cay San Cay Tre

(Plate 9. A & B)

Examined specimens. DT859 (female) was collected at 11°90753 N, 108°016004 E, alt. 967 m, in TD NR, on 22 December 2010; DT0493—94 (males), DT0495 (female) collected at 11°858815 N, 107°999309 E, alt. 910 m, in TD NR, on 17—18 April 2011

Diagnosis. Size small, SVL up to 25.66 mm; skin smooth; vomerine teeth absent; fingers free; dorsum yellow-bronze, with dark brown small spots, a light mid-dorsal line, and a pair of thick, bright yellow dorsolateral stripes; iris bicolor, bright golden dorsally and reddish brown ventrally (after Orlov et al., 2012).

Morphological characters. Habitus slender; size small, SVL 12.56—13.11 mm in males (n = 2), 10.93—12.15 mm in females (n = 2); head longer than broad; nostril round, closer to tip of snout than to eye; canthus rostralis sharp; loreal region oblique, concave; eye large, ED/SNL 0.66—0.99; IO/EUW1.23—1.79; tympanum round, TD/ED 0.46—0.66; supratympanic fold well defined; vomerine teeth absent; choanae round and hidden by upper jaw; tongue free and notched behind.

Relative finger length: I < II < IV < III; tips of fingers with enlarged round discs, with circummarginal grooves; fingers free of webbing; subarticular tubercles pronounced; inner metacarpal tubercle present; hind limbs slender with tibiotarsal articulation reaching to eye; heels overlap when legs are folded at right angles to body; discs of toes smaller than those of fingers; toes moderately developed webbed; subarticular tubercles on toes round and prominent; inner metatarsal tubercle oval, approximately 0.58—0.73 times in length of the first finger; outer metatarsal tubercle absent.

Skin on back and side of body and limbs smooth; venter smooth with fine granules, posterior part of belly and internal part of thigh granular; supra-anal dermal flap absent.

Coloration in life. Dorsum yellow-bronze with small, dark brown spots, a thin mid-dorsal line from tip of snout to vent; a pair of thick, bright yellow dorsolateral stripes, outlined with dark brown

posteriorly, extending from rear of eye to rump; lateral head light pinkish brown; upper park of flank dark brown, lower part pinkish brown; ventral surface of body pinkish white; upper surfaces of limbs bronze, thigh and tibia with some large, dark brown dots in irregular shapes; lower surfaces of limbs light grey, upper arm and inner part of thigh white; discs of fingers and toes grey; webbings grey; iris bright golden dorsally and reddish brown ventrally, both with brown reticulation; pupil horizontal ovoid, black (identification after Orlov et al., 2012).

Sexual dimorphism. Males with nuptial pads, white, bearing tiny spinules, on the first fingers.

Taxonomic remarks. The specimens differ from the original description of Orlov et al., (2012) by having ratio E-T/TD 0.39—0.57 (versus distance from tympanum to eye less than one-third tympanum diameter); relation of toe length: I < II < V < III < IV (versus I < II < III = V < IV); toe webbing reaching about midway between the proximal and middle subarticular tubercles on the inner side of the toe IV and reaching to the middle subarticular tubercle or between the distal and middle subarticular tubercles on the outer side of the toe IV (versus webbing reaching to the distal subarticular tubercle on both sides of the toe IV); tarsal fold absent (versus inner tarsal fold present).

Distribution. *T. bambusicolum* has been currently known from the localities of lowlands in southern Vietnam, including Binh Phuoc, Dak Nong, Lam Dong, and Dong Nai provinces, at elevations between 125 and 400 m (Orlov et al., 2012). Our specimens were found at higher elevations, up to 967 m.

Theloderma gordoni **Taylor, 1962**

English names: Gordon's Bug-eyed Frog, Gordon's Warted Frog, Large Warted Treefrog

Vietnamese name: Ech Cay San Go-don

(Plate 9. D & E)

Examined specimens. DT0481 (male) was collected at 11°828251 N, 108°033999 E, elev. 1425 m, in TD NR, on 09 March 2011.

Diagnosis. Size large; skin with very rough, with large and small tubercles; vomerine teeth present; fingers free of webbing; dorsum dark reddish brown; iris light olive-grey with black radial rays (after Rowley et al., 2011a).

Morphological characters. A large male individual (SVL 54.9 mm) matches the original description of *Theloderma gordoni* (Taylor, 1962) by having head round in dorsal view, as long as broad; snout truncated in dorsal view, and round in lateral view; tip of snout protruding to lower jaw; nostril round, closer to tip of snout than to eye; canthus rostralis distinct; loreal region concave; eye prominent, ED/SNL 0.7; tympanum round, E-T/TD 0.6; vomerine teeth present, arranged in two oblique rows, lengths of the rows shorter than distance between them; choanae distinct, oval, unhidden by upper jaw's margin; tongue notched behind at level of 0.21 times of its length.

Fore limbs slender; relative finger length: I < II < IV < III; tips of fingers with round discs, bearing circummarginal grooves; diameter of disc on the third finger half of tympanum diameter; fingers without webbing; subarticular tubercles on fingers round and physical; inner metacarpal tubercle elongated, 0.9 times in length of the first finger; two outer metacarpal tubercles, separated from each other; tibiotarsal articulation extending to eye; heels overlap when legs are folded at right angles to body; relative toe length: I < II < III < V < IV; discs on toes smaller than those on fingers; toe webbing well developed, formula: $I_{1½-2}II_{1-2}III_{1½-2¼}IV_{2-1}V$; inner metatarsal tubercle prominent, 0.6 times of the first toe length.

Skin of body and limbs covered by tubercles, irregular in shape and size, bearing granules; tubercles on head and back grouped in pronounced ridges; tubercles around cloaca thicker and more prominent; tubercles on lateral head and flank, dorsal surfaces of forearm and fingers round and denser than those on back; tubercles on dorsal surface of tarsus and toes larger and thicker than those on thigh and tibia; tubercles on thigh and tibia arranged

in long shape that modified black cross-bars; chin and throat with tubercles; chest, belly, and ventral surface of thigh coarsely granular.

Coloration in life. Dorsal surface dark reddish brown; ridges of tubercles dark brown; cross-bars on limbs black or reddish brown; ventral surface light grey with black reticulations; tubercles on hand, fingers, foot, and toes white; iris light olive-grey with black radial rays; pupil round, black.

Sexual dimorphism. Males bearing white nuptial pads, with minus spines, on dorsal and lateral surfaces of thumbs, appropriate half lengths of the thumbs.

Taxonomic remarks. The specimen differs from the original description of Taylor (1962) as follows: ratio IO/UEW 1.23—1.79 (versus ratio IO/UEW > 1.5); tympanum 0.7 times in length of eye (versus tympanum approximate 0.92 times in length of eye); subarticular tubercles present on all toes (versus subarticular tubercles present on only the three outer toes); outer metatarsal tubercle absent (versus the outer metatarsal present, very small and indistinct).

Distribution. This species has been reported from the type locality in Chiang Mai Province, Thailand and Vietnam in provinces of Lao Cai, Lai Chau, Vinh Phu, Bac Thai, Cao Bang, Long Son, Gia Lai, Kon Tum and Dong Nai, at elevations 700—1300 m (Dijk & Bain, 2004; Nguyen et al., 2009 and Frost, 2013). This is the first report of *T. gordoni* from Dak Nong Province, at elevation of 1425 m.

***Theloderma palliatum* Rowley, Le, Hoang, Dau & Cao 2011**

English names: Cloaked Moss Frog

Vietnamese name Ech Cay San Tra Hinh

(Plate 9. F—H)

Examined specimens. DT0422 (male) was collected at 12°07645 N, 108°678869 E, alt. 1685 m, on 14 June 2010; DT0913 (male) was

collected at 12°152022 N, 108°69502 E, alt. 1644 m, on 27 June 2011; DT0979 (male) was collected at 12°15326 N, 108°462475 E, alt. 2066 m, on 07 August; DT0073 (female) was collected at 12°094939 N, 108°660495 E, alt. 2027 m, on 21 March 2010 & DT0415 (female) was collected at 12°101601 N, 108°66933 E, alt. 1781 m, on 10 June 2010. All the specimens were collected from BDNP NP.

Diagnosis. Size small; skin with tiny tubercles; vomerine teeth absent, finger webbing absent; dorsum pale to medium brown with dark brown markings; iris bicolor, gold dorsally, dull reddish brown ventrally (after Rowley et al., 2011a).

Morphological characters. Size small, SVL 14.4—14.85 mm in males (n = 3), 10.45—10.83 mm in females (n = 2); snout blunt in dorsal view, truncated and proceeding lower jaw in lateral view; nostril closer to tip of snout than to eye; canthus rostralis distinct; loreal concave; eye large, ED/SNL 0.73—0.84; IO/UEW 1.11—1.50; tympanum distinct, round, smaller than eye diameter (TD/ED 0.48—0.70, E-T/TD 0.22—0.37); vomerine teeth absent; choanae small, nearly completely concealed under upper jaw; tongue free and bifid at rear.

Limbs slender; relative finger length: I < II < IV < III; tips of fingers enlarged into round discs, bearing circummarginal grooves; the third finger disc 0.3—0.8 times of tympanum diameter; fingers not webbed; subarticular tubercles on fingers round and prominent; inner metacarpal tubercle elongated; two outer metacarpal tubercles, oval, not in contact, the inner larger than the outer; relative toe length: I < II < III < V < IV; discs and subarticular tubercles on toes smaller than those on fingers; toes well webbed, webbing formula: $I_{2-2}II_{1½-2¾}III_{1¾-3}IV_{2½-1½}V$; dermal fringes along outer margins of the first and fifth toes absent; inner metatarsal tubercle long, prominent; outer metatarsal tubercle small, round.

Skin on dorsal surface rough with tiny granules; chin and throat smooth, belly and ventral surface of thigh coarsely granular.

Coloration in life. Dorsum yellow brown, with two dark brown blotches in orbital region, a large, dark brown spot on middle of

dorsum; lateral surface of head dark brown, edge of upper lip whitish; iris gold dorsally, dull reddish brown ventrally; pupil black (identification followed Rowley et al., 2011a).

Sexual dimorphism. Nuptial pad present in males, on dorsal and lateral surfaces of the thumb.

Distribution. *T. palliatum* was recently discovered from the evergreen forest of BDNB NP, in Lam Dong Province, at 1625 m elev., by Rowley et al. (2011a). Orlov et al. (2012) reported this species from the same forest at elevation of 1820 m. Our specimens were also found in the same forest, at elevations between 1680 and 2066 m.

***Theloderma stellatum* Taylor, 1962**

English names: Taylor's Bug-eyed Frog, Purple-spotted Warted Frog, Chantaburi Warted Treefrog

Vietnamese name: Ech Cay San Tay-lo

(Plate 9. I—K)

Examined specimens. DT0444 (female) was collected from 11º998053 N, 108º729327 E, alt. 616 m, in PB NP, on 23 September 2011. Photographs were taken on 17 August 2011, from SLSM.

Diagnosis. Size small; skin with tiny tubercles; vomerine teeth absent; fingers webbed; dorsum dark brown with creamy and dark brown markings; iris dark gold with dark brown reticulation (after Rowley et al., 2011a).

Morphological characters. The specimen was identified as *Theloderma stellatum* by having the following figures: SVL 33.0 mm (female, n = 1); head as long as wide; snout round in dorsal view, truncated and protruding to lower jaw in lateral view; nostril round, nearer to tip of snout than to eye; canthus rostralis indistinct; loreal region sloping and concave; eye prominent, ED/SNL 0.87, IO/UEW 1.08; tympanum round, large, TD/ED 0.57, E-T/TD 0.28; vomerine teeth absent; choanae small, partly concealed

by upper jaw's edge; tongue free posteriorly for a half of its length and notched behind for 0.19 times of its length.

Fore and hind limbs short; tips of fingers enlarged into round discs, with peripheral grooves; width of the third finger's disc smaller than tympanum diameter; fingers webbed, formula: $I_{2-3½}II_{2-3½}III_{3½-3½}IV$; subarticular tubercles noticeable; inner metacarpal tubercle small and prominent; two outer metacarpal tubercles, nearly in contact; tibiotarsal articulation reaching beyond to eye; heels in contact when legs are folded at right angles to body; discs on toes smaller than those on fingers; toes fully webbed, formula: $I_{1-2½}II_{2-2}III_{1½-2}IV_{2-1}V$; subarticular tubercles on toes similar to those on fingers; inner metatarsal tubercle pronounced, elongated, its length half of the first toe length; outer metatarsal tubercle absent.

Skin dorsally and laterally scattered with round tubercles and tiny granules; tubercles smaller and less dense on flank; ventral surface smooth but posterior part of belly and ventral surface of thigh coarsely granular; dermal flap above cloaca absent.

Color in life. Dorsal surface dark brown; some small, irregularly shapes, reddish cream and dark brown marks present in snout and interorbital regions; a larger mark, in "X" shape, reddish cream, running from rear of eye to level above of axilla region; a trifold, dark brown or black mark, near to the "X" shape mark; two round, creamy dots on middle of back: (1) the first dot blurry, on midway between tip of snout and vent; and (2) the second smaller, but more distinct in rump region; another large creamy patch on surface of posterior of back, vent, groin and thigh; flank dark brown, with a creamy patch at middle; axilla region dark grey; ventral surface dark brown marbling with white spots; brown cross-bars on dorsal surfaces of limbs, alternating in creamy and dark brown; tubercles on dorsum black or dark brown; tiny granules white; tubercles on hand and foot white; discs brown dorsally, light grey ventrally; iris dark gold with dark brown reticulation; pupil horizontal oval, black (identification followed Taylor, 1962; Stuart et al., 2006 and Rowley et al., 2011a).

Distribution. *T. stellatum* has been recorded from Cambodia, Lao, Thailand and Vietnam, at elevations between 50 and 1500 m (Stuart et al., 2006 and Frost, 2013). In Vietnam, this species has been known from Kon Tum, Gia Lai, Dak Lak, Dong Nai, Kien Giang provinces (Nguyen et al., 2009). These are the first records of this species from Ninh Thuan and Binh Thuan provinces.

***Theloderma truongsonense* (Orlov & Ho, 2005)**

English name: Truongson Bubble-nest Frog

Vietnamese name: Nhai Cay Truong Son

(Plate 9. L—N)

Examined specimens. DT0933 (male) was collected at 12°471149 N, 108°416678 E, alt. 1030 m, in CYS NP, on 15 October 2011.

Diagnosis. Habitus slender; size small; skin covered by small tubercles dorsally; vomerine teeth absent; fingers not webbed; dorsum pale brown with dark brown markings (after Orlov & Ho, 2005 and Rowley et al., 2011a).

Morphological characters. Body slender; SVL 24.5 mm (male, n = 1); head as long as wide, HL/SVL 0.4; snout pointed in dorsal view, SNL/HL 0.43; nostril round; eye large, ED/SNL 0.8; tympanum round with a raised rim, dorsally fused into temporal region; supratympanic fold distinct; vomerine teeth absent.

Limbs slender; tips of fingers with large discs; fingers without webbings; subarticular tubercles round and conspicuous; inner metacarpal tubercle long and prominent, half of the first finger length; discs and subarticular tubercles on toes similar to those on fingers but smaller in sizes; toes webbed, formula: $I_{2-2¼}II_{2-3½}III_{2-3½}IV_{3-2}V$; outer metatarsal tubercle and fold along tarsus absent.

Dorsal skin with tiny tubercles; a row of tubercles on upper eyelid, prominent; ventral surface granular; dermal fringes along outer edges of the first and fourth fingers, first and fifth toes, hand, and

lower arm, foot and tarsus absent; cloacae region with condense small tubercles.

Coloration in life. Dorsal surface yellow-brown or light brown; a long, dark brown mark, in "X" shape from anterior of eye through upper eyelid to rump; two black dots present in orbital region; three larger spots: one on middle of back and two others at rumps; some brown patches, in irregular shapes present in snout, axilla, and cloacal regions; granules on dorsum white; lateral head brown; a black stripe under the canthus rostralis, supratympanic fold, continuing backward to flank; upper part of flank light brown, the rest part white reticulated with dark brown; chin and throat brown; belly and ventral surfaces of upper arm and thigh white with dark brown flecks; dorsal surfaces of limbs dark yellow to brown, with few irregular dark brown speckles; discs on fingers and toes grey dorsally and fleshy white ventrally (after Orlov & Ho, 2005).

Sexual dimorphism. Males with nuptial pads, on dorsal and lateral of the thumbs, reaching from base to distal edges of subarticular tubercles of the fingers.

Taxonomic remarks. The specimen differs from previous descriptions by having the following characters: ratio of TD/ED 0.67, E-T/TD 0.22 (versus TD/ED 0.89, E-T/TD 0.33, respectively, in the original description of Orlov & Ho, 2005); the first finger shorter than the second (versus the first finger as long as the second in the description of Orlov & Ho, 2005); the third toe shorter than the fifth toe (versus the third and fifth toes in the same size in the description of Orlov & Ho, 2005); iris bicolor, one-third dorsally dull reddish orange and dark brown ventrally (versus iris pale gold above, reddish brown bellow in the report of Rowley et al., 2011a); choanae small, hidden under inner edge of upper jaw; tongue notched at rear, at levels 0.45 times of its length and free posteriorly for 0.13 times of its length; hind limbs long, with tibiotarsal articulation touching to nostril; heels overlap when legs are folded at right angles to body (not mentioned by Orlov & Ho, 2005).

Distribution. This species has been reported from Central Highlands of Vietnam in Quang Binh, Quang Tri, Thua Thien Hue, Da

Nang, Kon Tum, Gia Lai, and Dak Lak provinces, at elevations of 300−1400 m. (Nguyen et al., 2009 and Frost, 2013).

2. Distributional patterns of amphibians in the Langbian Plateau

2.1. Geographical distribution

The non-metric multidimensional scaling (NMDS) plot from the Bray-Curtis dissimilarity matrix, with confidence ellipses that show where 95% of sites of the same forests are expected to occur indicates that there were overlaps of anuran species compositions among populations from the five forests of the BDNB NP, CYS NP, PB NP, TD NR & SLSM (Figure 8 A).

Results from adonis test show that there was no significant difference in anuran faunas among the forests within the study area, p = 0.05 after 999 permutations. Post hoc comparisons using Turkey HSD test indicate that only the

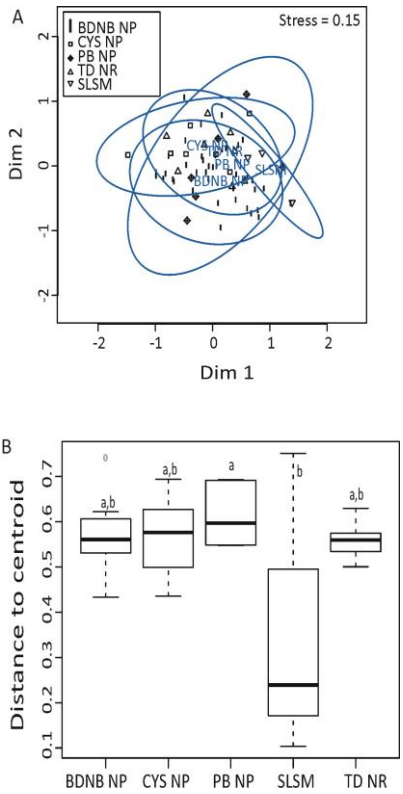

Figure 8. (A) NMDS ordination graph (scaling 1) of a Bray-Curtis dissimilarity matrix of anuran assemblages from the Langbian Plateau and their 95% confidence ellipses. (B) The distances to centroid in relationship with different forests (BDNB NP, CYS NP, PB NP, TD NR, & SLSM) for the anuran assemblages in the Langbian Plateau.

Turkey levels not sharing the same letter are significantly different.

anuran fauna of the SLSM significantly differed from that of the PB NP (Figure 8 B).

2.2. Habitat partitioning

Among 44 recorded anurans, nine species were found in the cloud forests, 32 species in the evergreen forests, 21 species in the mixed forests composed of hardwoods and bamboo, 18 species in the mixed forests composed of small hardwoods and bamboo, and 11 species in the cultivated areas (Figure 9 A). Habitat features of the forest types are shown in Plate 10.

Result of adonis test indicates that the anuran assemblages were significantly different in species compositions among types of the forests, $p < 0.01$ after 200 permutations. Result of betadisper test shows significant differences in dispersion within the same forest types, $p < 0.01$ based on 999 permutations. Post hoc comparisions using Turkey HSD test show evidence of a significant difference in species compositions between anuran communities in the evergreen forests

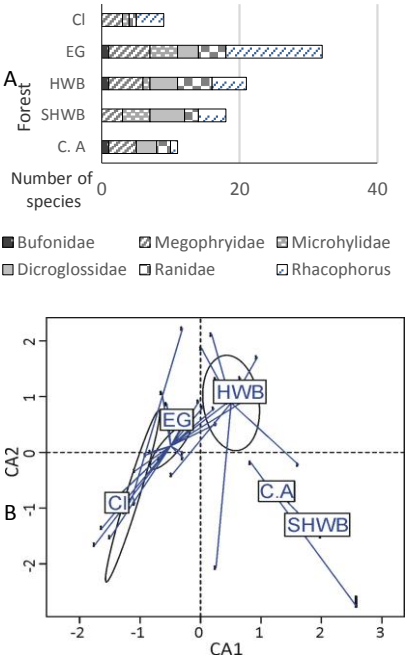

Figure 9. (A) Species richness and family composition of the anurans in the Langbian Plateau versus forest types. (B) CA ordination graph (scaling 1) for the anuran assemblages using present/absence data of 44 species at 38 survey sites in different forest types of the Langbian Plateau, with their connecting sites to the centroids and 95% confidence ellipses.

Cl: cloud forest; EG: evergreen forest; HWB: mixed forest of hardwoods and bamboo; SHWB: mixed forest of small hardwoods and bamboo; C. A: cultivated area.

and those in the mixed forests composed of hardwoods and bamboo, $p < 0.01$. The anuran species compositions of the assemblages of the mixed forests composed of hardwoods and bamboo were also significantly different from those of the mixed forests composed of small hardwoods and bamboo, $p = 0.02$.

The CA biplot shows that the anuran communities in the cloud forests are more similar to those in the evergreen forests than to those in the other forest types. The anuran species compositions of assemblages of the evergreen forests were more similar to those of the mixed forests composed of hardwoods and bamboo than to those of the cultivated areas (Figure 9 B).

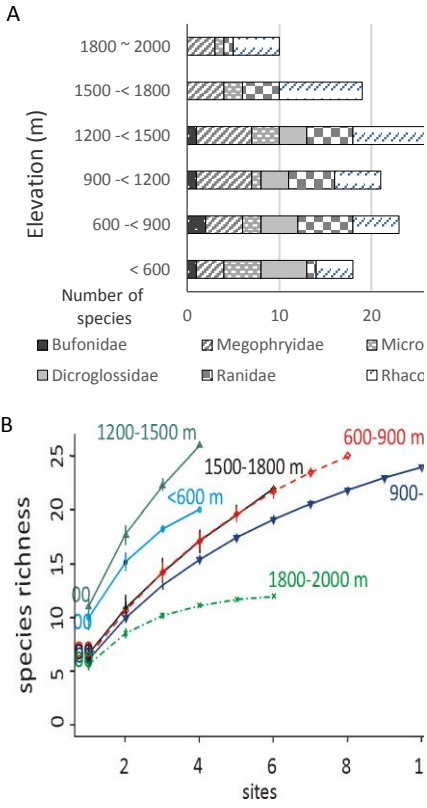

Figure 10. (A) Species richness and family composition of the anurans in the Langbian Plateau versus elevation ranges. (B) Species accumulation curves for various elevations of the amphibian assemblages of the Langbian Plateau.

2.3. Altitudinal distribution

In terms of altitudinal distribution, the species richness of the community becomes high from 900 m, peaks at elevations approximate 1500 m (26 species), and gradually declines at higher elevations of above 1800 m, with the species richness of 22 species at elevations

1500−1800 m and 10 species at elevations of 1800−2000 m (Figure 10 A).

The species accumulation curves for the assemblages of amphibians at various elevations in the study area show the same trends as well (Figure 10 B). The species accumulation curve for the elevations 1800−2000 m (the dash line with "X" symbols) is the lowest and nearly reaches the horizon. This indicates that chance for new amphibians recorded in sites of the elevations 1800−2000 m becomes limited. Conversely, the species accumulation curve for the elevations 1200−1500 m is the highest and still in steep condition.

The number of species recorded from sites at the elevations up to 600 m is estimated of 20 for a sample size of four sites, only lower than that from sites at the elevations of 1200−1500 m. However, the slope of the species accumulation curve for the elevations up to 600 m, in comparison with other species accumulation curves for the study area, decreases from the sample size of three sites.

Results of adonis and betadisper tests show evidence of significant differences in species compositions among anuran communities at different ranges of elevations in the Langbian Plateau, $p < 0.01$ based on 200 permutations. These differences were not caused by different within-group dispersions, $p = 0.64$ after 999 permutations.

The CCA biplot for the anuran communities at different ranges of elevations in the study area suggests that the species *Rhacophorus vampyrus*, *Theloderma palliatum*, *Feihyla palpebralis*, *Microhyla* sp. 2, and *Leptobrachium leucops* are associated with the elevations above 1500 m while the group of species *Microhyla pulchra*, *Kaloula pulchra*, *Occidozyga lima*, *Limnonestec dabanus*, *Chiromantis nongkhorensis*, and *Theloderma stellatum* are limited with the elevations below 900 m. This biplot with the 95% confidence ellipses estimated for each range of elevations also shows overlaps of species compositions of the anuran assemblages among the elevations, from 600 to 1800 m (Figure 11).

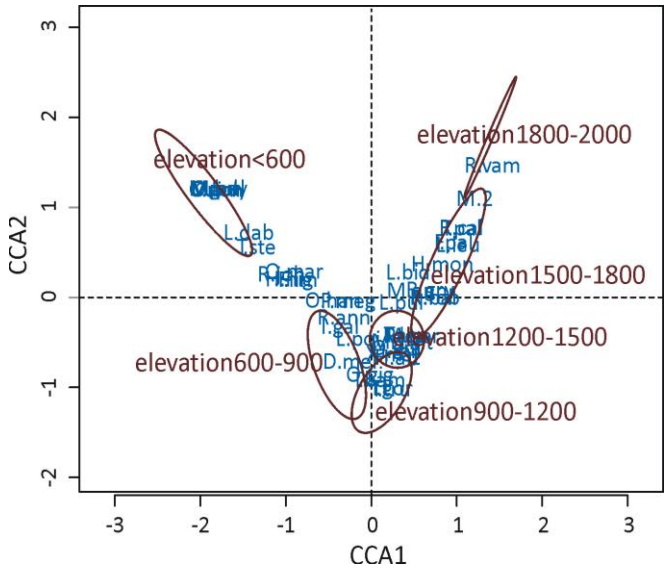

Figure 11. CCA ordination graph (scaling 2) for the anuran assemblages of the Langbian Plateau, using present or absence data of 44 species at 38 survey sites, with 95% confidence ellipse for each range of elevations.
The species are named with abbreviation of the first letter of the Genus and three letters for species name.

2.4. Ecological niche segregation of amphibians in the Langbian Plateau

Distribution patterns of the amphibian species were observed in different spatial scales. In this study, I also focused on life-mode segregation of amphibian species in the Langbian Plateau. Many species were associated with source of water with a distance around one meter. Number of species declined with increasing the distance from the water bodies in both vertical and horizontal dimensions (Table 3 & Figure 12).

Microhabitat utilization of the anuran communities in the Langbian Plateau are presented in Table 3 and Plate 11.

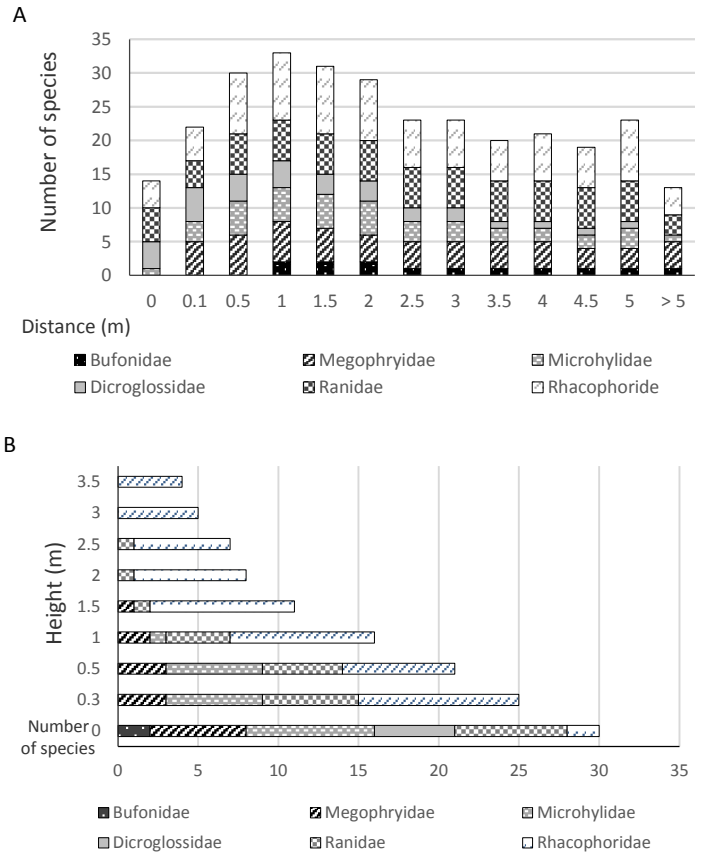

Figure 12. Species richness and family composition of the anurans in the Langbian Plateau versus (A) distance from water bodies and (B) high level above the ground.

Table 3. Microhabitat utilizations of amphibians in the Langbian Plateau.
(D: maximum distance that frogs could move away from the water body; H: maximum height above the ground where the frogs were found; 1: ponds, shallow water; 2: slow moving flow streams; 3: fast moving flow streams; 4: waterfalls; 5: underground shelters; 6: under or on leaf litter; 7: on large rocks; 8: in rocky crevices; 9: in clay holes in stream banks; 10: under grasses, shrubs; 11: on grasses, shrubs; 12: on small trees; 13: on trunk of large trees).

	Distance (m)		Aquatic				Terrestrial						Arboreal		
Species	D	H	1	2	3	4	5	6	7	8	9	10	11	12	13
Duttaphrynus	2	0	-	-	-	-	-	+	-	-	-	+	-	-	-

	Distance (m)		Aquatic				Terrestrial						Arboreal		
Species	D	H	1	2	3	4	5	6	7	8	9	10	11	12	13
melanostictus															
Ingerophrynus galeatus	> 5	0	-	-	-	-	-	+	-	-	-	+	-	-	-
Brachytarsophrys intermedia	> 5	0	-	+	-	-	-	+	-	+	-	+	-	-	-
Leptobrachium leucops	> 5	0	-	-	-	-	+	+	-	-	-	+	-	-	-
Leptobrachium pullum	> 5	0	-	-	-	-	+	+	-	-	-	+	-	-	-
leptolalax bidoupensis	4	1.5	-	+	-	-	-	+	-	+	+	+	+	-	-
Ophryophryne hansi	1.5	0.5	-	+	-	-	-	+	+	+	-	+	+	-	-
Xenophrys major	> 5	1	-	-	+	+	-	+	+	-	-	+	+	-	-
Calluella guttulata	0	0	+	-	-	-	-	-	-	-	-	-	-	-	-
Kaloula pulchra	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Microhyla annamensis	2	0.5	-	-	-	-	-	+	-	-	-	+	+	-	-
Microhyla berdmorei	> 5	0	-	-	-	-	-	+	-	-	-	+	-	-	-
Microhyla heymonsi	2.5	0.5	+	-	-	-	-	+	-	-	-	+	+	+	-
Microhyla pulchra	2	0.5	-	-	-	-	-	+	-	-	-	+	-	-	-
Microhyla sp. 1	5	0.5	-	-	-	-	-	+	-	-	-	+	-	-	-
Microhyla sp. 2	5	0.5	-	+	-	-	-	+	-	-	-	+	+	-	-
Occidozyga lima	< 0.5	0	+	-	-	-	-	-	-	-	-	-	-	-	-
Occidozyga martensii	< 0.5	0	+	-	-	-	-	+	-	-	-	-	-	-	-
Fejervarya limnocharis	3	0	+	+	-	-	-	-	-	-	-	+	-	-	-
Limnonectes dabanus	2	0	-	+	-	-	-	+	-	-	-	-	-	-	-
Limnonectes poilani	5	0	+	+	-	-	-	-	-	-	-	-	-	-	-
Hylarana attigua	5	1	-	+	-	-	-	+	-	-	-	+	+	+	-
Hylarana milleti	5	1	+	+	+	-	-	+	+	+	+	+	+	+	-
Hylarana montivaga	5	1	+	+	-	-	-	+	+	+	+	+	+	+	-

Species	Distance (m)		Aquatic				Terrestrial						Arboreal		
	D	H	1	2	3	4	5	6	7	8	9	10	11	12	13
Hylarana nigrovittata	5	1	-	+	-	-	-	+	+	+	+	+	+	+	-
Odorrana gigatympana	> 5	< 0.5	-	-	-	-	-	+	+	-	-	-	+	+	-
Odorrana graminea	> 5	2.5	-	+	+	+	-	+	+	-	+	+	+	+	-
Rana johnsi	> 5	0	-	-	-	-	-	+	-	-	-	+	-	-	-
Chiromantis nongkhorensis	1.5	1.5	-	-	-	-	-	-	-	-	-	-	+	+	-
Feihyla palpebralis	1.5	1.5	-	+	-	-	-	-	-	-	-	-	+	-	-
Kurixalus baliogaster	4	0.5	-	+	-	-	-	-	-	-	-	-	+	+	-
Polypedates megacephalus	> 5	3.5	+	+	-	-	-	+	-	-	-	+	+	+	-
Polypedates cf. *mutus*	> 5	3.5	+	-	-	-	-	-	-	-	-	-	+	+	-
Raorchestes gryllus	> 5	> 3.5	-	-	-	-	-	-	-	-	-	-	+	+	+
Rhacophorus annamensis	2	>3.5	+	+	-	-	-	-	-	-	-	-	+	+	+
Rhacophorus calcaneus	5	>3.5	-	+	-	-	-	-	-	-	-	+	+	+	+
Rhacophorus robertingeri	3	2.5	-	-	-	-	-	-	-	-	-	+	-	+	-
Rhacophorus vampyrus	5	3	-	-	-	-	-	-	-	-	-	-	-	+	+
Theloderma asperum	5	< 0.5	-	+	-	-	-	-	-	-	-	-	+	+	+
Theloderma bambusicolum	> 5	1	-	+	-	-	-	-	-	-	-	-	-	+	-
Theloderma gordoni	> 5	< 0.5	-	-	-	-	-	-	-	-	-	-	-	+	-
Theloderma palliatum	> 5	< 0.5	-	+	-	-	-	-	-	-	-	+	+	+	-
Theloderma stellatum	5	2	-	-	-	-	-	-	-	-	-	-	-	-	+
Theloderma truongsonense	1	<1	-	+	-	-	-	-	-	-	-	-	-	+	-

There were 13 types of three categories of aquatic, terrestrial, and arboreal microhabitats, used by the amphibians in the study area, including 27 aquatic species, 28 terrestrial species and 28 arboreal species. The aquatic group is represented by *Occidozyga* and

Calluella that seem to limit to lentic water bodies and stream species (e.g., *Limnonectes poilani*, *Odorrana graminea*) while Megophryidae, Microhylidae and *Hylarana* are typical species of the terrestrial group and treefrogs of the genus *Rhacophorus* and *Theloderma* are members of the arboreal group.

The CCA triplot for relationships of the amphibian assemblages with their microhabitat using and altitude levels in the study area indicates that the number of microhabitat types used by the amphibians is correlated with altitude. The sites at the higher elevations could provide the more terrestrial and arboreal microhabitat types but the less aquatic microhabitat types for amphibians (Figure 13).

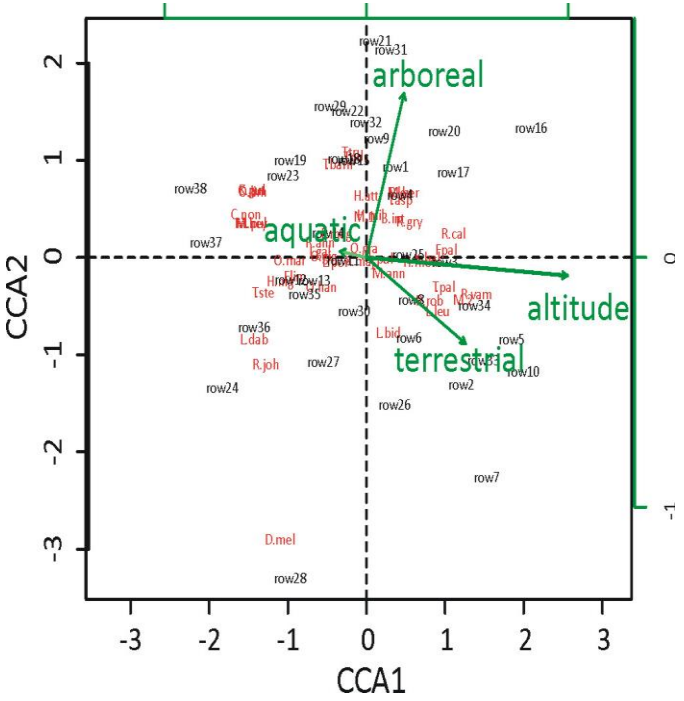

Figure 13. CCA ordination graph for the amphibian assemblages in the Langbian Plateau, related to microhabitat utilization and altitude level.

3. Biogeographic relationships of the amphibian communities among forests within and neiboring the Langbian Plateau

3.1. Biogeographic relationships of the amphibian communities among the forests within the Langbian Plateau

The amphibian fauna of CYS NP based on the data of this study and data reported by Birdlife (2010) was used for evaluating biogeographic relationships of the amphibian communities among the forests within the Langbian Plateau. Data of amphibian fauna of the eastern hills of Cambodia (Stuart et al., 2006) was also used for the analyses.

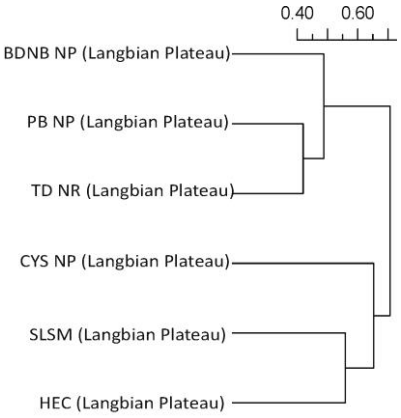

Figure 14. Hierarchical cluster analyses using matrix of Jaccard distance among of the amphibian communities within the Langbian Plateau, including BDNB NP, CYS NP, PB NP, TD NR, SLSM and the eastern hills of Cambodia (HEC).

Figure 14 presents the results obtained from the cluster analysis. The cluster of the amphibian fauna of the eastern hills of Cambodia joints with that of the SLSM. This indicates that species composition of the eastern hills of Cambodia is more similar to that of the SLSM than to those of other communities within the Langbian Plateau. Of 29 species recorded from the eastern hills of Cambodia (Stuart et al., 2006), 19 were found from the study area as well.

3.2. Biogeographic relationship of amphibian communities between the Langbian Plateau and adjacent areas

Data of amphibian faunas of the Kon Tum Plateau, northern the Langbian Plateau, and of Cardamom Mountains in Cambodia, southwestern the Langbian Plateau, reported from previous

studies, were used for estimating biogeographic relationship of amphibian species compositions between the Langbian Plateau and adjacent areas.

The Kon Tum Plateau harbors an assemblage of 75 amphibian species (Inger et al., 1999; Orlov, 2005; Bain et al., 2006; Orlov et al., 2006b; Rowley et al., 2010d; Rowley et al., 2011a; Nishikawa et al., 2012; Rowley et al., 2012a). Of this fauna, 38 species share with the fauna of the Langbian Plateau, appropriate of 50.67% species composition of the Kon Tum Plateau and 59.38% species composition of the Langbian Plateau. Among the pairswise ecological distances between the amphibian communitities of the Kon Tum Plateau and those of the forests within the Langbian Plateau, the distance between the fauna of the Kon Tum Plataeau and that of the CYS NP is the smallest 0.70 (Table 4). This reveals that the amphibian community of the Kon Tum Plateau is more similar to that of the CYS NP than to those of other forests within the Langbian Plateau.

Table 4. Distance matrix for the amphibian communities of the forests within and adjacent the Langbian Plateau, using the Jaccard distance.
(HEC: Eastern hills of Cambodia; KT: Kon Tum Plateau, Vietnam; CAR: Cardamom Mountains of Cambodia)

	BDNB NP	CYS NP	PB NP	TD NR	SLSM	HEC	KT
CYS NP	0.66						
PBNP	0.54	0.65					
TD NR	0.43	0.67	0.42				
SLSM	0.78	0.69	0.67	0.69			
HEC	0.78	0.61	0.73	0.74	0.56		
KT	0.80	0.70	0.82	0.82	0.78	0.74	
CAR	0.88	0.76	0.89	0.92	0.78	0.71	0.73

Of 41 species of the amphibian fauna of the Cardamom Moutains (Ohler et al., 2002; Grismer et al., 2008a; Grismer et al., 2008b), 21 species also were found in the Langbian Plateau, appropriate of 51.22% species composition of the Cardamom Mountains and 32.81% species composition of the Langbian Plateau. Data from the Table 4 shows that the ecological distance between the amphibian faunas of the Cardamom Mountains and the eastern hills of

Cambodia is the smallest (0.71), among the ecological distances between the fauna of the Cardamom Mountains and those of the forests within the Langbian Plateau. This indicates that the amphibian fauna of the Cardamom Mountains is more intensive overlapping with that of the eastern hills of Cambodia than with those of other sites within the Langbian Plateau.

The Jaccard distance of the amphibian faunas between the Langbian and Kon tum plateaus (0.62) smaller than that between the Langbian Plateau and the Cardamom Moutains (0.74) shows that t he species composition of the Langbian Plateau (Southern Annamites subregion) has a higher similarity with that of the Kon Tum Plateau (Central Annamites subregion) than with that of the Cardamom Moutains. The Jaccard distance of the amphibian fauna between the Kon Tum Plateau and that of the Cardamom Moutains is 0.73.

4. Bioacoustics

4.1. Megophryidae

Brachytarsophrys intermedia

A total of 13 advertisement calls emitted by three males that inhabited in a stream in BDNB NP were recorded at a temperature of 21.4^{o}C and a relative humidity of 97.7%.

Acoustic properties (Figure 15 A & Table 5). Calls had a duration of 0.664−5.425 s, repeating at a rate of 0.04−0.34 calls/s, and inter-call intervals of 6.822−30.03 s. Each call contained 2−10 notes of approximately 0.099−0.24 s in duration. The notes were repeated at rates of 1.38−2.80 notes/s and the inter-note intervals were 0.267−0.611 s. Each note was composed of 5−20 pulses and repeated at a rate of 31.00−95.51 pulses/s.

Frequencies ranged from 0.09 to 5.18 kHz. The fundamental frequency was 0.3−0.39 kHz, with three or four harmonics. The dominant frequency was on the second harmonic at 0.56−0.82 kHz. Details of characters of the calls are presented in Table 5.

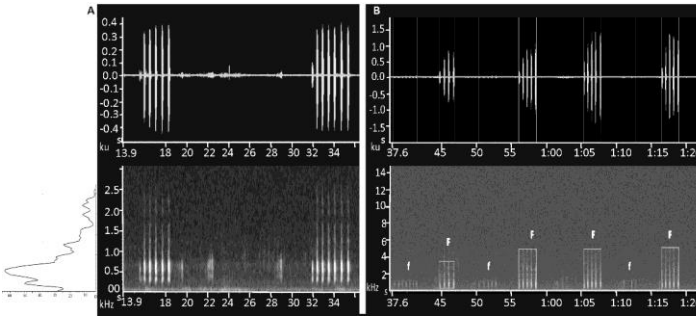

Figure 15. (A) Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of calls of *Brachytarsophrys intermedia*. (B) Spectrogram showing call alternation pattern in interaction between a frog (F) and human mimic call (f).

Table 5. Acoustic properties of advertisement calls of *Brachytarsophrys intermedia.*

Individuals	DT0261	DT0262	DT0263
Number of measured call(s)	9	2	3
Call duration (s)	2.72 ± 1.074 (0.664–4.284)	3.995 ± 2.02 (2.565–5.425)	2.51 ± 1.08 (1.431–3.597)
Inter-call interval (s)	14.483 ± 7.56 (6.822–30.027)	12.725	13.74 ± 0.46 (13.416–14.073)
Call repetition rate (calls/s)	0.34	0.04	0.06
Number of note per call	5.78 ± 2.05 (2–9)	10	5 ± 2 (3–7)
Note duration (s)	0.219 ± 0.29 (0.099–2.176)	0.209 ± 0.02 (0.192–0.24)	0.191 ± 0.01 (0.149–2.14)
Note repetition rate (notes/s)	1.74 ± 0.26 (1.38–2.04)	1.66	2.2 ± 0.72 (1.4–2.8)
Inter-note interval (s)	0.408 ± 0.05 (0.342–0.611)	0.371 ± 0.06 (0.267–0.49)	0.39 ± 0.05 (0.292–0.45)
Number of pulses per note	13.65 ± 2.60 (5–18)	18.20 ± 0.79 (17–20)	16.40 ± 2.59 (8–18)
Pulse repetition rate (pulses/s)	71.15 ± 11.05 (31.00–95.51)	82.68 ± 5.88 (68.09–88.54)	80.91 ± 12.60 (37.23–89.01)
Frequency band (kHz)	0.21 ± 0.03 5.10 ± 0.98 (0.17–5.18)	0.15 ± 0.09 2.46 ± 0.02 (0.09–2.47)	0.20 ± 0.02 2.54 ± 0.15 (0.19–2.71)
Dominant Frequency (kHz)	0.79 ± 0.02 (0.78–0.82)	0.62 ± 0.09 (0.56–0.69)	0.63 ± 0.02 (0.60–0.65)
Fundamental frequency (kHz)	0.39	0.3	0.3

Calling behavior. This species has pattern of call alternation in response to neighbor's calls (Figure 15 B). Calls of frog (F) might be trigged by human mimic calls (f) that achieved a similar dominant frequency at around 0.65−0.86 kHz. Results from acoustic analyses show that the frog (F), in responding to the simulated signals (f), produced alternating calls and gradually raised the sound pressure level and the number of notes in its calls.

The calling males were deeply concealed in large rocky crevices. The smallest distance between the two calling frogs was about 1 m. The calls of this species could be heard from a great distance, both during day and at night.

Leptobrachium leucops

Calls emitted by two males of *L. leucops* that inhabited the forest of PB NP were recorded at temperatures and relative humidity of 23.7^{o}C & 85% and 26.1^{o}C & 79.8% for each individual, respectively.

Acoustic properties (Figure 16 and Table 6). Calls were composed of a single pulsed note, lasting for 0.073−0.077 s, repeated at a rate of 0.09 calls/s and inter-call intervals of 5.112−16.719 s. Each note consisted of 10−11 pulses, delivered at a rate of 121.62−129.87 pulses/s. Frequencies of calls ranged from 0.62 to 2.59 kHz. The dominant frequency equaled the fundamental frequency, presenting at about 1.22−1.36 kHz.

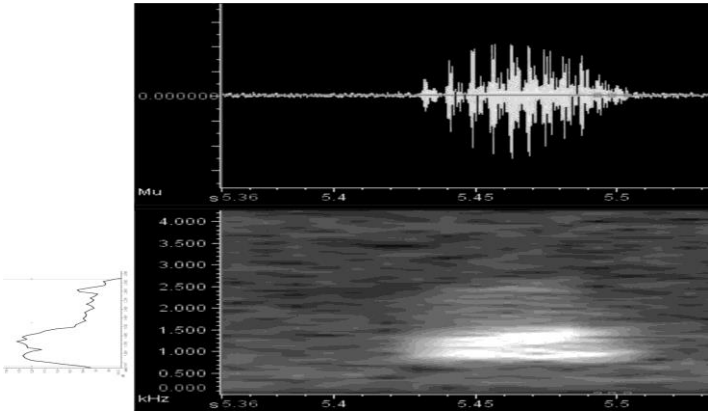

Figure 16. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Leptobrachium leucops*, at a temperature of 23.7°C and a humidity of 85%.

Table 6. Acoustic properties of advertisement calls of *Leptobrachium leucops*.

Individual	DT0453	DT0454
Forest	PB NP	PB NP
SVL (mm)	47.5	43.0
Temperature (°C)	23.7	26.1
Humidity (%)	85	79.8
Number of measured call(s)	3	1
Call duration (s)	0.074 ± 0.001 (0.073–0.074)	0.077
Inter-call interval (s)	10.92 ± 8.21 (5.11–16.72)	–
Number of note per call	1	1
Number of pulses per note	10	11
Pulse repetition rate (pulses/s)	122.18 ± 0.96 (121.62–123.29)	129.87
Frequency band (kHz)	0.67 ± 0.04 2.57 ± 0.04 (0.63–2.59)	0.61–1.74
Dominant Frequency (kHz)	1.28 ± 0.07 (1.22–1.36)	1.22

Calls of males from PB NP share similar vocal characters with those of males from BDNB NP according to the description of Stuart et al., (2011) although they were a single note (versus calls of males from BDNB NP composed of 1−5 notes). Thus the durations of calls, between 0.073−0.077 s, were shorter than those of 0.10−1.70 s, in the description of Stuart et al., (2011).

Calling behavior. The calling males of *L. leucops* were found hidden in burrows under the ground or under leaf litter, far from the stream (3−5 m away). Sometimes, they were also met calling under the leaves of bushes.

Leptobrachium pullum

Calls were recorded from five males in the forests of BDNB NP, TD NR, and SLSM. Environmental conditions in which the frogs emitted calls are shown in Table 7.

Acoustic properties (Figure 17 and Table 7). Calls of *L. pullum* were a single pulsed note of 0.172−0.308 s in duration, with a repetition rate of 0.07−0.37 calls/s, and inter-call intervals 3.055−30.595 s. Each call had 14−34 pulses, repeated at a rate of 68.29−111.11 pulses/s. Frequencies of the calls ranged from 0.42 to 5.51 kHz. The dominant frequency was the fundamental frequency, at 0.99−1.38 kHz.

Table 7. Acoustic properties of advertisement calls of *Leptobrachium pullum*.

Individual	DT0305	DT0688	DT0959	AMNH16847	AMNH16848
Forest	BDNB NP	TD NR	TD NR	SLSM	SLSM
SVL (mm)	48.5	45.1	45.3	48.3	48.6
Temperature (°C)	18.5	22.2	17	27.5	27.2
Humidity (%)	84.9	80.2	100	78.8	79.6
Number of measured call(s)	3	3	2	7	10
Call duration (s)	0.295 ± 0.01 (0.282−0.308)	0.192 ± 0.02 (0.172−0.205)	0.264 ± 0.03 (0.235−0.294)	0.201 ± 0.02 (0.179−0.223)	0.191 ± 0.01 (0.177−0.202)

Individual	DT0305	DT0688	DT0959	AMNH1684 7	AMNH1684 8
Inter-call interval (s)	11.059 ± 5.02 (7.509–14.609)	3.726 ± 0.11 (3.649–3.803)	11.128 ± 3.25 (8.831–13.425)	4.345 ± 1.17 (3.055–6.365)	8.004 ± 8.75 (3.473–30.595)
Call repetition rate (call/s)	0.09	0.24	0.09 ± 0.02 (0.07–0.11)	0.22	0.37
Number of note(s) per call	1	1	1	1	1
Number of pulses per note	32.33 ± 1.53 (31–34)	14.67 ± 0.58 (14–15)	25.50 ± 2.65 (22–28)	21.14 ± 0.90 (20–22)	20.70 ± 0.95 (19–22)
Pulse repetition rate (pulses/s)	106.09 ± 1.23 (104.73–107.14)	71.53 ± 3.71 (68.29–75.58)	92.89 ± 5.02 (88.44–99.26)	100.48 ± 4.70 (94.17–106.15)	103.13 ± 4.20 (98.45–111.11)
Band of frequency (kHz)	0.83 ± 0.05 5.44 ± 0.06 (0.77–5.51)	0.56 ± 0.02 2.56 ± 0.25 (0.54–2.72)	0.93 ± 0.16 1.68 ± 0.16 (0.81–1.89)	0.48 ± 0.04 2.41 ± 0.93 (0.42–2.53)	0.5 ± 0.05 1.46 ± 0.06 (0.44–1.55)
Dominant frequency (kHz)	1.29 –	1.19 ± 0.05 (1.16–1.25)	1.35 ± 0.06 (1.25–1.38)	1.05 ± 0.05 (0.99–1.12)	1.13 ± 0.04 (1.08–1.16)

The calls have the same variety of temporal and spectral characters as those in the description of Stuart et al. (2011).

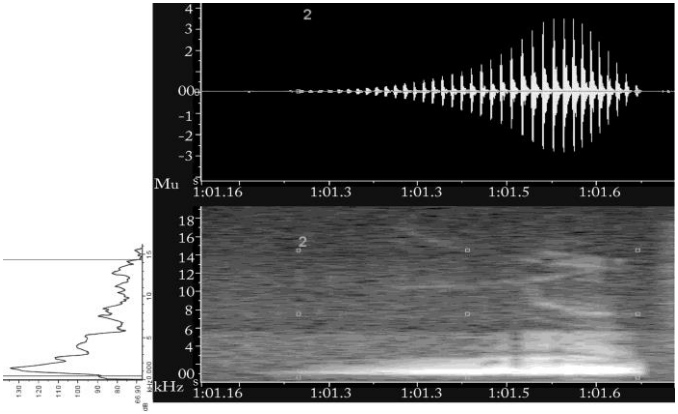

Figure 17. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Leptobrachium pullum*, at a temperature and a humidity of 23.7°C & 85%, respectively.

Calling behavior. Males of *L. pullum* often emitted calls when sitting under small shrubs, or leaf litter and fallen tree, sometimes, in burrows under the ground. They were also observed emitting

calls in chorus. The smallest distance between two calling males was approximate 1−1.5 m.

This species performed a call alternation pattern in response to neighbor's calls (Figure 18 A & D). The bioacoustic results show that when audio signals from neighboring frogs appeared, the calls were produced with longer duration 0.342 ± 0.20 s, $t(13.56) = 2.4$, $p = 0.03$; lower dominant frequency 1.02 ± 0.06 kHz, $t(38.98) = 5.3$, $p < 0.01$; and higher intensity 87.70 ± 1.66 dB, $t(26.74) = 6.6$, $p < 0.01$ than those in condition before the occurrence of neighbor's signals (call duration: 0.216 ± 0.04 s; dominant frequency: 1.17 ± 0.11 kHz; average intensity: 63.20 ± 19.20 dB). Pulse repetition rate of calls, in case of neighboring signals present, was significantly slower 97.74 ± 10.93 pulses/s, $t(23.4) = 7.4$, $p < 0.01$ than those in condition of being alone, approximate 68.52 ± 12.55 pulses/s. There was no significant difference in inter-call interval $t(19.45) = 0.1$, $p = 0.96$ and in number of pulses per note $t(38.41) = 0.1$, $p = 0.7$ between calls of males being alone and calls of males co-occurring with neighbors.

Encounter call (Figure 18 B). After responding to other neighbor's signals for a period of time, in this case 30−35 s, a calling male could introduce a new type of call. Later, the competitor of the focal frog also produced similar calls of this new type.

The new calls were one single note, lasting on average 0.646 ± 0.22 (0.307−1.029, n = 10 calls). Each note consisted of 26.00 ± 3.53 pulses (19.0−30.0, n = 10 notes) that were repeated at an average rate of 41.83 ± 11.57 pulses/s (28.12−65.15, n = 10 repetitions). Average dominant frequency was 1.03 ± 0.06 kHz (0.90−1.07, n = 10 calls). Average intensity was 86.67 ± 2.69 dB (81.7−91.1, n = 10 calls).

The encounter calls were produced with significantly longer duration 0.299 ± 0.03 s, $t(9.08) = 5.0$, $p < 0.01$; higher pulse number per note 26.00 ± 3.53, $t(10.36) = 4.4$, $p < 0.01$; lower pulse repetition rate 41 ± 11.57 pulses/s, $t(10.43) = 6.7$, $p < 0.01$; and lower average intensity 86.67 ± 2.69 dB, $t(10.21) = 2.8$, $p = 0.02$ than those of the advertisement calls produced in response to neighboring vocal

signals (call duration 0.646 ± 0.0.22 s; pulses number per note 20.97 ± 1.79; pulse repetition rate 67.17 ± 6.02 pulses/s; average intensity 89.09 ± 1.28 dB). There was no significant difference in dominant frequency, t (12.99) = 0.3, p = 0.7 between encounter calls and advertisement calls.

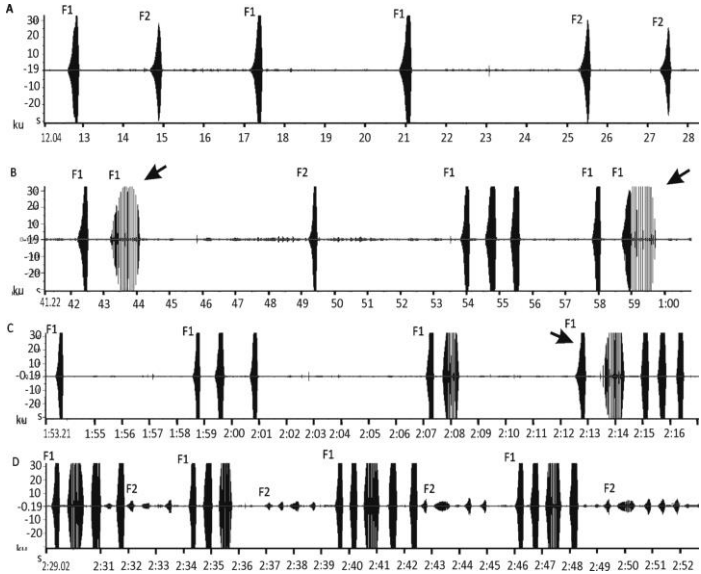

Figure 18. Oscillogram showing evolution of creating compound calls in *Leptobrachium pullum*.

(A) Alternation pattern in advertisement calls in interaction between two frogs (F1 & F2). (B) Encounter calls produced by frog F1. (C) Compound calls produced by frog F1. (D) Alternation pattern in compound calls in interaction between two frogs F1 & F2.

Compound calls (Figure 18 C). Groups were compounded of one encounter call and 1−4 advertisement calls, continued on average 1.403 ± 0.43 s (0.894−2.155, n = 8 groups), with an average gap of 4.339 ± 1.16 s (2.308−6.147, n = 7 intervals). Within the group, calls were produced with an average interval of 0.380 ± 0.19 s (0.232−0.935, n = 21 intervals).

The encounter calls, often the second or third call, lasted on average of 0.568 ± 0.16 s (0.307−0.881, n = 8 calls) and consisted of

25.50 ± 3.66 pulses (19−30, n = 8 calls). This call recurred on average of 45.25 ± 10.26 pulses/s (29.51−65.15, n = 8 repetitions). Average dominant frequency was 1.02 ± 5.37 kHz (0.95−1.08, n = 8 calls). Average intensity was 87.76 ± 1.53 dB (85.70−91.10, n = 8 calls).

Advertisement calls lasted on average of 0.304 ± 0.03 s (0.274−0.383, n = 22 calls), contained 20.55 ± 1.74 pulses per note (18−26, n = 22 calls). Average pulse repetition rate was 64.54 ± 5.0 pulses/s (54.79−72.73, n = 22 repetitions). Average dominant frequency was 1.02 ± 0.06 kHz (0.95−1.08, n = 22 calls). Average intensity of the call was 89.70 ± 1.06 dB (87.50−92.90, n = 22 calls).

There was no significant difference in call duration $t(29.18) = 1.6$, $p = 0.13$; number of pulses $t(25.76) = 1.9$, $p = 0.06$; and dominant frequency $t(29) = 18.3$, $p = 0.32$ between advertisement calls in the compounds and those not grouped in the compounds.

The advertisement calls in the compound calls had a significantly lower pulse repetition rate $t(25.4) = 4.1$, $p < 0.01$ and a significantly higher average intensity $t(3) = 6.8$, $p < 0.01$ than those of the advertisement calls not in groups of compound calls (pulse repetition rate: 71.62 ± 4.97 pulses/s & average intensity: 82.30 ± 0.84 dB).

There was no significant difference in pulse number $t(1.97) = 1.05$, $p = 0.4$ and dominant frequency $t(1.18) = 0.9$, $p = 0.5$ of the encounter calls between in the compound calls and of those not in the compound calls. In the compound calls, the encounter calls were produced with a shorter average duration 0.568 ± 0.16 s, $t(2.55) = 4.4$, $p = 0.03$; higher pulse repetition rate 45.25 ± 10.26 pulses/s, $t(7.00) = 4.7$, $p < 0.01$; and higher average intensity 87.76 ± 1.53 pulses/s, $t(3.01) = 6.8$, $p < 0.01$ in comparison with the encounter calls not grouped in the compound calls (call duration: 0.959 ± 0.10 s; pulse repetition rate 28.15 ± 0.04 pulses/s; and average intensity 82.30 ± 0.84 dB).

Leptolalax bidoupensis

The analyzed calls were produced by eleven males from four populations in the forests of BDNB NP, PB NP, TD NR and SLSM, at a temperatures of 12.9−26.4°C and a relative humidity of 79.5−100% (see Table 8 for details).

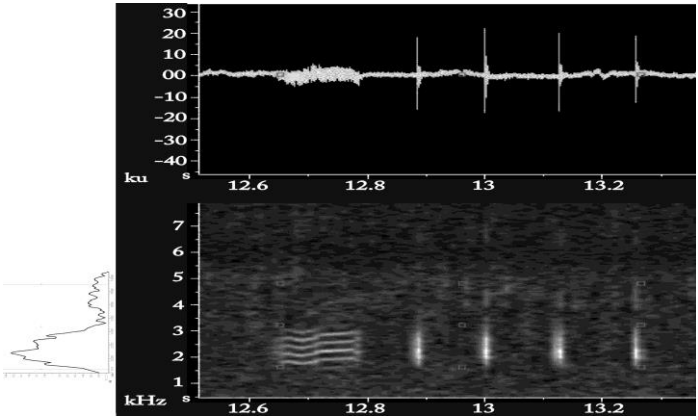

Figure 19. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Leptolalax bidoupensis*, from TD NR, at a temperature 12.9°C and a relative humidity of 100%.

Acoustic properties (Figure 19 and Table 8). Calls emitted by males of *L. bidoupensis* had a duration of 0.055−1.586 s, a call repetition rate of 0.04−0.74 calls/s, and inter-call intervals of 0.289−28.998 s. Each call was comprised of 2−38 unpulsed notes, with or without an initial note and usually followed by five shorter notes. The initial note was 0.043−0.457 s in duration. The subsequent notes were 0.002−0.042 s in duration, note repetition rates approximate 5.48−23.33 notes/s, and inter-note intervals were 0.006−0.138 s. Band of frequencies of the calls varied from 0.81 to 29.29 kHz. The dominant frequency was 2.20−3.45 kHz.

Variation. Results indicate that the calls produced by males among the four populations (BDNB NP, PB NP, SLSM, and TD NR) significantly varied in temporal properties: call duration $F(3, 7) = 29.56$, $p < 0.01$; inter-call interval $F(3, 7) = 7.58$, $p = 0.01$; number

of notes per call F (3, 7) = 96.11, p < 0.01; and note repetition rate F (3, 7) = 12.58, p < 0.01. There was no significant difference in duration of subsequent note and dominant frequency of calls of males among the four populations, F (3, 7) = 4.1, p = 0.06 and F (3, 7) = 1.24, p = 0.36, respectively (Figure 20).

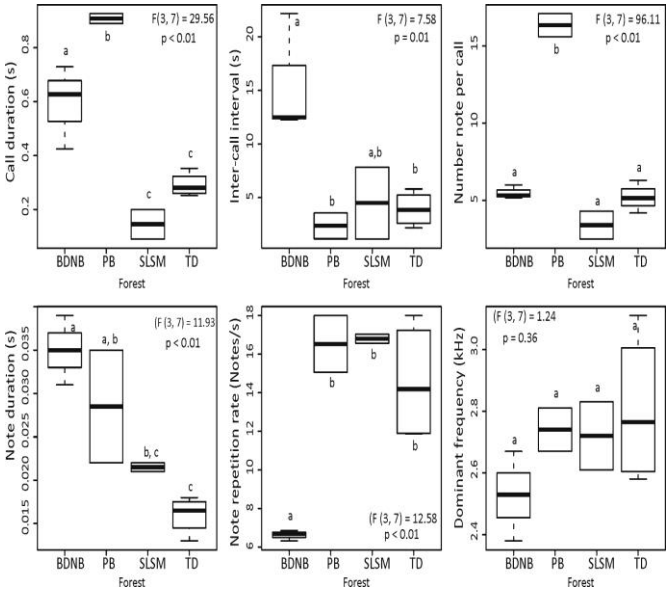

Figure 20. Variations in vocal properties of males *Leptolalax bidoupensis* among populations in the Langbian Plateau.

BDNB: population in BDNB NP; PB NP: population in PB NP; SLSM: population in SLSM; TD: population in TD NR. Turkey levels not sharing the same letter are significantly

Calls emitted by males in PB NP had the longest duration (0.908 ± 0.03 s), followed by those of calls of males in BDNB NP (0.594 ± 0.15 s), and those of calls of males in TD NR (0.292 ± 0.04 s), that were similar to those of calls of males in SLSM (0.145 ± 0.08 s, p = 0.34). Calls of males in BDNB NP also significantly differed from those of males in other populations in inter-call interval (BDNB NP: 15.626 ± 5.66 s; PB NP: 2.361 ± 1.11 s; SLSM: 4.492 ± 4.75 s; TD: 3.919 ± 1.63 s), all p < 0.01.

Calls of males in PB NP had significantly higher number of notes per call (16.35 ± 1.06) than those of males in BDNB NP (5.50 ± 0.44), those of males in TD NR (5.20 ± 0.86), and those of males in SLSM (3.40 ± 1.27), all $p < 0.01$. Calls of males in BDNB NP were significantly differed from those of males in other populations in note repetition rates, $p < 0.01$ (BDNB NP: 6.62 ± 0.27 notes/s; PB NP: 16.53 ± 2.09 notes/s; SLSM: 16.80 ± 0.33 notes/s; and TD NR: 14.56 ± 3.15 notes/s).

Body size and environmental effects. The analyses data revealed that the larger individuals could emitted the calls that have longer inter-call interval $r(9) = 0.78$, $p < 0.01$; lower note repetition rate, $r(9) = -0.90$, $p < 0.01$; and lower dominant frequency $r(9) = -0.75$, $p < 0.01$.

There was no significant correlation between environmental temperature and relative humidity conditions and vocal signals of this species $F(1, 7) = 1.88$, $p = 0.51$.

Calling behavior. Males often called from small rocky crevices or clay holes inside banks of the streams, or under thick leaf litter, or under leaves of small shrubs along banks of the streams.

The oscillogram of the calls shows that *L. bidoupenesis* performed a pattern of call alternation for dealing with neighboring calls (Figure 21). Results reveal that in case of other vocal signals from neighbors present, calls of the focal frog were emitted with a longer duration 0.322 ± 0.05 s, $t(17) = 5.0$, $p < 0.01$; shorter inter-call intervals 0.938 ± 2.1 s, $t(27.7) = 9.3$, $p < 0.01$; higher number notes per call 6.30 ± 1.16 notes/call, $t(25.9) = 12.7$, $p < 0.01$; and higher note repetition rate 16.57 ± 4.05 notes/s, $t(12.56) = 5.0$, $p < 0.01$ than those of calls of the frog in case of being alone (call duration: 0.240 ± 0.03 s; inter-call interval: 3.747 ± 0.98 s; number of notes per call: 3.14 ± 0.38; and note repetition rate: 9.24 ± 3.18 notes/s). There was no significant difference in note duration $t(38.8) = 1.0$, $p = 0.34$; dominant frequency $t(9.7) = 1.2$, $p = 0.2$; and intensity $t(13.1) = 2.1$, $p = 0.06$ of calls between two periods before and after the occurrence of neighboring vocal signals.

Table 8. Acoustic properties of advertisement calls of *Leptolalax bidoupensis*.

Individuals	DT00526	DT0916	DT0917	DT0440	DT0455
Forest	BDNB NP	BDNB NP	BDNB NP	PB NP	PB NP
SVL (mm)	30.1	27.9	27.9	25.3	23.6
Temperature (°C)	14	21.4	21.4	23.3	24.1
Humidity (%)	100	79.5	79.5	93.4	83
Number of measured calls	3	6	6	10	10
Call duration (s)	0.425 ± 0.15 (0.613–0.745)	0.627 ± 0.13 (0.487–0.83)	0.729 ± 0.08 (0.614–0.849)	0.926 ± 0.4 (0.403–1.586)	0.889 ± 0.28 (0.617–1.461)
Inter-call interval (s)	22.16 ± 9.67 (15.32–28.998)	12.474 ± 4.04 (8.821–19.294)	12.244 ± 4.89 (6.302–18.351)	1.151 ± 0.89 (0.526–3.264)	3.57 ± 1.69 (0.664–5.162)
Call repetition rate (calls/s)	0.04	0.08	0.08	0.44	0.22
Number of notes per call	5.33 ± 0.58 (5–6)	5.17 ± 0.98 (4–7)	6.00 ± 0.63 (5–7)	15.6 ± 9.54 (7–38)	17.10 ± 5.60 (12–30)
Note repetition rate (notes/s)	6.32 ± 0.18 (6.36–6.71)	6.68 ± 0.89 (5.48–8.03)	6.85 ± 0.23 (6.51–7.14)	15.05 ± 3.58 (11.11–23.33)	18.00 ± 0.91 (16.54–19.85)
Initial note duration (s)	0.140 ± 0.01 (0.134–0.146)	0.179 ± 0.01 (0.159–0.194)	0.180 ± 0.02 (0.145–0.192)	0.230 ± 0.15 (0.081–0.457)	0.146 ± 0.01 (0.093–0.211)
Note duration (s)	0.006 ± 0.002 (0.004–0.009)	0.006 ± 0.002 (0.003–0.008)	0.006 ± 0.001 (0.004–0.008)	0.014 ± 0.01 (0.002–0.031)	0.012 ± 0.01 (0.004–0.025)
Inter-note interval (s) (between initial note & note 2)	0.095 ± 0.001 (0.094–0.096)	0.08 ± 0.016 (0.054–0.095)	0.094 ± 0.004 (0.089–0.098)	0.028 ± 0.009 (0.012–0.039)	0.028 ± 0.005 (0.019–0.042)
Inter-note interval (s) (between subsequent notes)	0.121 ± 0.01 (0.107–0.138)	0.102 ± 0.02 (0.035–0.117)	0.107 ± 0.004 (0.1–0.114)	0.034 ± 0.01 (0.006–0.059)	0.033 ± 0.01 (0.021–0.049)
Frequency band (kHz)	1.60 ± 0.70 4.67 ± 0.09 (1.54–4.78)	1.42 ± 0.94 5.55 ± 0.10 (1.28–5.70)	1.36 ± 0.15 8.03 ± 0.22 (1.20–8.35)	1.42 ± 0.82 3.39 ± 0.2 (1.27–3.72)	1.88 ± 0.11 3.25 ± 0.14 (1.81–3.46)
Dominant frequency (kHz)	2.38 ± 0.17 (2.20–2.54)	2.67	2.53 ± 0.03 (2.50–2.58)	2.67 ± 0.07 (2.58–2.76)	2.81 ± 0.03 (2.76–2.84)

Table 8. Acoustic properties of advertisement calls of *Leptolalax bidoupensis* (continued).

Individuals	DT0950	DT0686	DT0692	DT0975	AMNH17590	AMNH17567
Forest	TD NR	TD NR	TD NR	TD NR	SLSM	SLSM
SVL (mm)	24.8	24.2	22.9	28	24.6	23.6
Temperature (°C)	15.7	22.3	22.3	12.9	26.4	26.2
Humidity (%)	100	80.6	80.6	100	81.8	81.8
Number of measured calls	10	10	10	10	10	2
Call duration (s)	0.353 ± 0.03 (0.331–0.413)	0.294 ± 0.02 (0.281–0.325)	0.252 ± 0.03 (0.183–0.3)	0.268 ± 0.04 (0.238–0.356)	0.2 ± 0.03 (0.176–0.264)	0.091 ± 0.05 (0.055–0.126)
Inter-call interval (s)	5.8 ± 0.94 (4.716–7.928)	2.179 ± 0.43 (1.85–3.146)	3.025 ± 1.38 (1.127–5.074)	4.67 ± 0.91 (3.059–5.58)	1.134 ± 0.76 (0.289–2.387)	7.849 ± 6.26 (3.42–12.28)
Call repetition rate (calls/s)	0.16	0.40	0.30	0.20	0.74	0.28
Number of notes per call	5.20 ± 0.42 (5–6)	6.3 ± 0.48 (6–7)	5.1 ± 0.73 (4–6)	4.20 ± 0.42 (4–5)	4.30 ± 0.48 (4–5)	2.50 ± 0.70 (2–3)
Note repetition rate (notes/s)	11.87 ± 0.66 (11.56–12.41)	18.00 ± 0.73 (17.48–19.74)	16.47 ± 1.72 (12.15–18.18)	11.90 ± 0.57 (10.91–12.61)	16.57 ± 2.47 (13.89–22.73)	17.03 ± 1.63 (15.87–18.18)
Initial note duration (s)	–	–	–	–	0.061 ± 0.01 (0.043–0.081)	–
Note duration (s)	0.016 ± 0.010 (0.003–0.029)	0.013 ± 0.003 (0.009–0.023)	0.018 ± 0.007 (0.007–0.042)	0.017 ± 0.01 (0.011–0.04)	0.009 ± 0.004 (0.006–0.021)	0.023 ± 0.007 (0.016–0.035)
Inter-note interval (s) (between initial note and note 2)	–	–	0.037 ± 0.005 (0.028–0.044)	0.066 ± 0.002 (0.062–0.069)	0.03 ± 0.004 (0.023–0.035)	0.29
Inter-note interval (s) (between subsequent notes)	0.064 ± 0.004 (0.054–0.075)	0.04 ± 0.01 (0.008–0.047)	0.037 ± 0.004 (0.027–0.045)	0.059 ± 0.01 (0.045–0.068)	0.037 ± 0.004 (0.024–0.044)	0.02
Frequency band (kHz)	2.00 ± 0.03 3.80 ± 0.35 (1.95–4.33)	1.64 ± 0.16 1.44 ± 1.14 (1.33–1.54)	2.02 ± 0.19 8.98 ± 1.68 (1.69–29.29)	1.21 ± 0.25 5.91 ± 0.31 (0.81–6.38)	1.58 ± 0.2 3.61 ± 0.32 (1.42–4.3)	1.64 ± 0.05 3.90 ± 0.09 (1.60–3.96)
Dominant frequency (kHz)	2.58 ± 0.14 (2.45–2.84)	2.9 ± 0.08 (2.67–2.93)	3.11 ± 0.15 (2.93–3.45)	2.63 ± 0.08 (2.50–2.76)	2.83 ± 0.09 (2.63–2.93)	2.61 ± 0.03 (2.58–2.63)

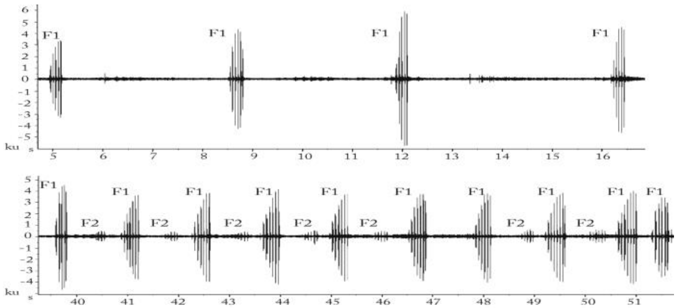

Figure 21. Timing relationship of calls between two neighboring *Leptolalax bidoupensis*.

Above: Calls emitted by frog F1 in case without neighbor's (F2) audio signals occur. Below: Pattern of call alternation performing of frog F1 in responding to calls of frog F2. All the calls were belonging to one recording.

Xenophrys major

A total of nine calls produced by three males from BDNB NP and PB NP were recorded. Environmental condition details related to each calling male are shown in Table 9.

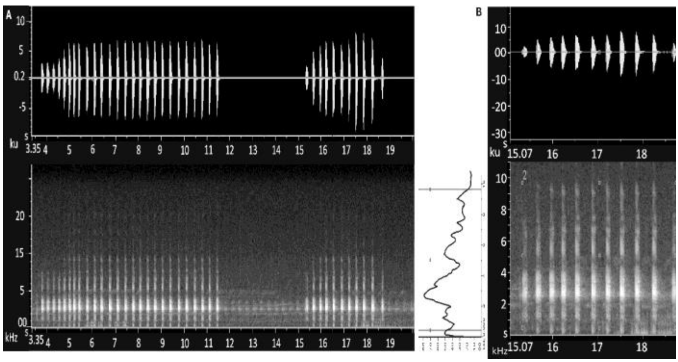

Figure 22. (A) Osciilogram (above) and spectrogram (below) of two calls of *Xenophrys major*, from BDNB NP, at a temperature and a humidity of 23°C & 86.3%, respectively. (B) Oscillogram (above), spectrogram (below, right), and power spectrum (below left) of the second call.

Acoustic properties (Figure 22 and Table 9). Calls were 1.560–7.755 s in length, consisted of 9–26 notes, and reoccurred with an interval of

2.505–3.811 s. The notes were continuous pulse trains, remained in a durations of 0.041–0.228 s, and repeated at a rate of 1.67–4.28 notes/s. Inter-note intervals were 0.077–0.935 s. Band of frequencies was 0.42–12.62 kHz. The dominant frequency equaled the second harmonic at 2.21–3.10 kHz.

Calling behavior. Calling males of this species were often found sitting on the ground, under small bushes or fallen trees in the forests.

Table 9. Acoustic properties of advertisement calls of *Xenophrys major*.

Individuals	DT0010	DT0427	DT0439
Forest	BDNB NP	BDNB NP	PB NP
SVL (mm)	60.8	67	65.8
Temperature (°C)	23	23	22.1
Humidity (%)	86.3	90	94
Number of measured call(s)	1	2	6
Call duration (s)	5.40	5.58 ± 3.08 (3.40–7.76)	3.30 ± 1.90 (1.56–6.93)
Inter-call interval (s)	–	3.811	2.88 ± 0.34 (2.505–3.350)
Call repetition rate (calls/s)	–	0.07	0.14
Number of notes per call	10	18.50 ± 10.60 (11–26)	12.83 ± 4.83 (9–22)
Note duration (s)	0.133 ± 0.002 (0.13–0.137)	0.101 ± 0.006 (0.082–0.113)	0.144 ± 0.048 (0.041–0.228)
Note repetition rate (notes/s)	1.67 ± 3.08	3.08 ± 0.20 (2.94–3.22)	3.81 ± 0.50 (3.03–4.31)
Inter-note interval (s)	0.452 ± 0.24 (0.277–0.935)	0.212 ± 0.052 (0.119–0.341)	0.122 ± 0.025 (0.077–0.214)
Frequency band (kHz)	0–22.05	3.57 ± 0.64 9.51 ± 0.52 (0–10.59)	1.51 ± 0.57 5.36 ± 2.13 (0.47–13.21)
Dominant frequency (kHz)	2.41	2.21	2.51 ± 0.15 (2.24–3.10)

4.2. Ranidae

Hylarana attigua

In total 21 calls produced by three males from CYS NP at temperatures of 23.4–26.5°C and humidity of 100% were analyzed (see Table 10 for details).

Acoustic properties (Figure 23 and Table 10). Males of this species produced two types of calls that delivered at a rate of 0.03–0.19 calls/s and inter-call intervals of 0.731–46.152 s.

Table 10. Acoustic properties of advertisement calls of *Hylarana attigua.*

Individuals	DT0537	DT0550	DT0555	DT0550	DT0555
Forest	CYS NP	CYS NP	CYS NP	CYS NP	CYS NP
SVL (mm)	42.8	38.1	41.8	38.1	41.8
Temperature (%)	100	100	100	100	100
Humidity (%)	23.4	26.5	26.5	26.5	26.5
Call type	1	1	1	2	2
Number of measured calls	5	11	4	5	6
Call duration (s)	0.233 ± 0.03 (0.187–0.269)	0.366 ± 0.22 (0.131–0.714)	0.228 ± 0.06 (0.152–0.277)	0.035 ± 0.01 (0.025–0.052)	0.037 ± 0.01 (0.029–0.044)
Inter-call interval (s)	30.488 ± 15.02 (13.157–46.152)	8.004 ± 7.51 (0.731–25.921)	3.94 ± 2.30 (2.36–6.59)	5.91 ± 3.36 (2.63–11.20)	5.65 ± 3.92 (1.50–11.05)
Number of pulses per call	87.40 ± 14.67 (63–100)	117.36 ± 72.93 (39–222)	97.25 ± 35.42 (53–139)	9.20 ± 2.39 (6–12)	12.50 ± 3.27 (6–15)
Pulse repetition rate (pulse/s)	369.24 ± 25.76 (331.55–393.44)	316.75 ± 29.49 (256.14–371.42)	417.62 ± 94.05 (332.13–514.93)	245.48 ± 75.63 (134.62–307.69)	312.46 ± 81.38 (166.67–413.79)
Frequency band (kHz)	0.76 ± 0.03 4.55 ± 0.26 (0.71–4.83)	0.85 ± 0.05 4.11 ± 0.42 (0.77–4.57)	0.83 ± 0.07 4.84 ± 0.13 (0.75–4.97)	0.79 ± 0.07 3.92 ± 0.63 (0.69–4.66)	0.76 ± 0.07 4.84 ± 0.29 (0.68–5.17)
Dominant frequency (kHz)	2.49 ± 0.05 (2.41–2.54)	2.59 ± 0.09 (2.45–2.76)	2.82 ± 0.13 (2.67–2.93)	2.43 ± 0.17 (2.24–2.67)	2.56 ± 0.15 (2.28–2.71)

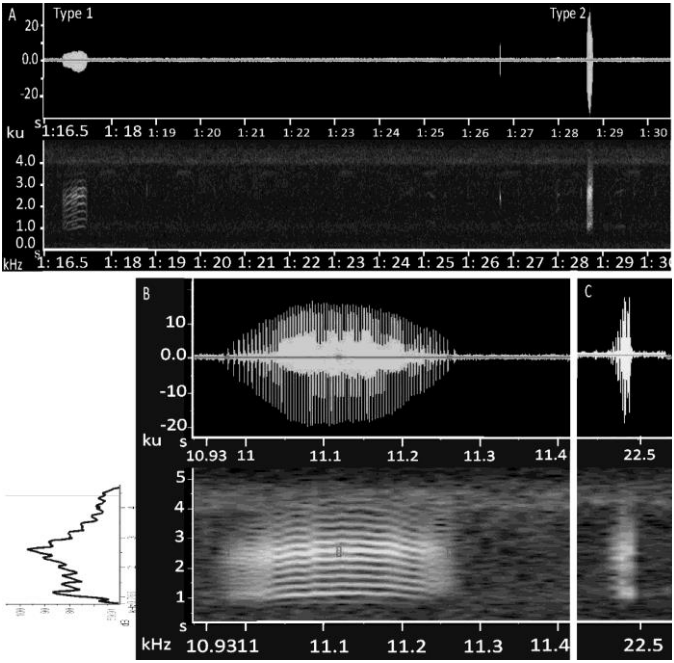

Figure 23 (A) Oscillogram (above), spectrogram (below) of calls of *Hylarana attigua*, from CYS NP, at a temperature of 26.5°C and a humidity of 100%. (B) Call type 1 with power spectrum (below, left); & (C) Call type 2.

Call type 1 was a single well-pulsed note, lasted for 0.131−0.714 s. Each note was composed of 39−222 pulses, repeated at a rate of 256.14−514.92 pulses/s. Frequency band ranged from 0.71 to 4.97 kHz. The fundamental frequency was 1.03−1.51 kHz. The dominant frequency was 2.41−2.93 kHz.

Call type 2 was a single note, composed of 6−15 pulses, repeated at a rate of 134.62−413.79 pulses/s and retained in a period of 0.025−0.052 s. Frequency band was 0.68−5.17 kHz. The fundamental frequency was 1.03−1.81 kHz. The dominant frequency was 2.24−2.71 kHz.

Calling behavior. Males called from branches of small trees and bushes, far from the water bodies (1−2 m away).

Hylarana milleti

In total 60 calls recorded from six males in BDNB NP, CYS NP, and TD NR, at ambient conditions of 20.4−23.4°C & 77−100% humidity were analyzed.

Acoustic properties (Figure 24 and Table 11). Calls were only one note, emitted with duration of 0.050−0.089 s, and a repetition rate of 0.40−1.52 call/s. Periods of time between the calls were 0.427−6.978 s. Each note was composed of 14−24 pulses and repeated at a rate of 232.14−340.00 pulses/s. Frequency band was 0.13−19.46 kHz. The dominant frequency was 1.16−3.14 kHz.

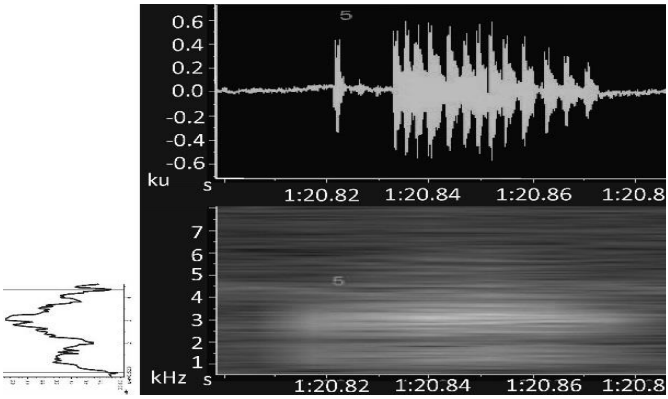

Figure 24. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Hylarana milleti* from CYS NP, at a temperature 23.4°C and a humidity of 100%.

Variation. Differences in call properties emitted by males among the three populations were not significant except for call duration, F (2, 3) = 14.68, p = 0.03. Durations (0.080 ± 0.003 s) of calls emitted by males in BDNB NP were significantly longer than those emitted by males in TD NR (0.059 ± 0.008 s), p =0.04 and by males in CYS NP (0.056 ± 0.002 s), p = 0.03. There was no

significant difference in duration between calls of males in CYS NP and those of males in TD NR, p = 0.83.

Calling behavior. Calling males were often found sitting on perches or on the ground, far from the water bodies (0.5 m away). This species has the behavior of gathering together for choruses and breeding aggregations.

Acoustic analyses of calls produced by a male in a chorus showed that when calls from other neighboring individuals occurred, the calling male made some changes in its calls as follows (Figure 25): (1) adjusted timing of the calls in alternation pattern; (2) decreased number of pulses within each note from 20.6 ± 1.35 to 18.78 ± 2.85, t (28.35) = 3.1, p < 0.01; (3) decreased rate of pulse repetition from 304.82 ± 14.00 pulses/s to 264.61 ± 20.46 pulses/s, t (17.92) = 7.6, p < 0.01; (4) increased intensity of the calls from 75.92 ± 0.72 dB to 76.02 ± 1.87 dB, t (37.83) = 0.3, p = 0.78; and (5) introduced an extra-note which was composed of 15.65 ± 1.77 pulses (13−21, n = 17), continued in a duration of 0.058 ± 0.01 s (0.053−0.072, n = 17), and separated from the first note in a short gap 0.086 ± 0.02 s (0.055−0.130, n = 17).

There was no significant difference in call duration t (35.49) = 1.7, p = 0.10 and in dominant frequency t (11.84) = 1.0, p = 0.35 between calls of male in responding to neighboring audio signals and those of the male staying alone.

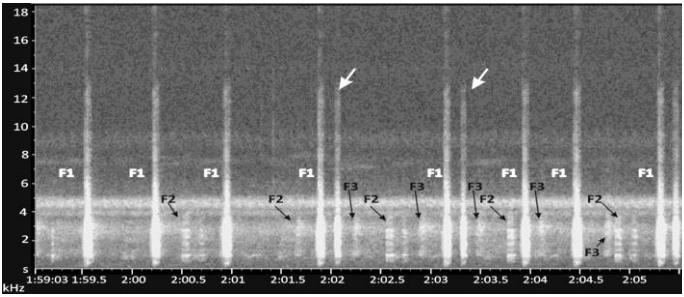

Figure 25. Spectrogram showing alternation pattern in advertisement calls of *Hylarana milleti* in interaction among three individuals (F1, F2 & F3). Frog F1 introduced the "extra-note" in the 4th & 5th calls (white arrows).

Table 11. Acoustic properties of advertisement calls of *Hylarana milleti*.

Individual	DT0709	DT0713	DT0429	DT0507	DT0535	DT0538
Forest	TD	TD	BDNB	BDNB	CYS	CYS
SVL (mm)	37.2	36.4	33.3	33.6	34.7	34.7
Temperature (°C)	21.8	22.3	20.8	20.4	23.4	23.4
Humidity (%)	94.1	80.6	77	80	100	100
Number of measured calls	10	10	10	10	10	10
Call duration (s)	0.064 ± 0.003 (0.058–0.069)	0.053 ± 0.003 (0.050–0.056)	0.078 ± 0.002 (0.074–0.081)	0.082 ± 0.003 (0.077–0.089)	0.057 ± 0.005 (0.051–0.064)	0.054 ± 0.002 (0.051–0.058)
Inter-call interval (s)	0.690 ± 0.14 (0.529–0.931)	0.930 ± 0.35 (0.677–1.790)	0.917 ± 0.23 (0.671–1.469)	2.380 ± 1.82 (1.350–6.978)	0.059 ± 0.167 (0.427–0.984)	0.072 ± 0.14 (0.482–0.903)
Call repetition rate (calls/s)	1.31	1.01	1.00	0.40	1.52	1.29
Number of pulses per call	20.6 ± 1.35 (18–23)	18	21.9 ± 0.99 (20–23)	23.1 ± 0.87 (22–24)	17.8 ± 1.48 (15–20)	14.8 ± 0.79 (14–16)
Pulse repetition rate (pulses/s)	304.82 ± 13.99 (285.71–333.33)	322.63 ± 15.40 (303.57–340.00)	269.33 ± 11.13 (253.16–285.71)	270.22 ± 15.03 (247.19–289.7)	294.35 ± 10.06 (274.51–313.73)	256.35 ± 1.19 (232.14–277.78)
Frequency band (kHz)	0.32 ± 0.15 19.15 ± 0.2 (0.13–19.46)	0.70 ± 0.11 11.70 ± 0.2 (0.51–11.94)	0.60 ± 0.16 14.86 ± 0.09 (0.27–14.95)	0.94 ± 0.08 7.12 ± 0.69 (0.82–7.96)	0.59 ± 0.1 8.43 ± 0.25 (0.36–8.75)	0.74 ± 0.11 7.04 ± 0.4 (0.53–7.82)
Dominant frequency (kHz)	2.89 ± 0.16 (2.62–3.06)	2.68 ± 0.06 (2.58–2.76)	2.17 ± 0.66 (1.16–2.76)	2.76 ± 0.06 (2.67–2.84)	3.09 ± 0.06 (2.97–3.14)	3.01 ± 0.06 (2.89–3.06)

Hylarana nigrovittata

One recording of a male from SLMS forest was taken at a temperature and a humidity of 26.5°C & 85 %, respectively.

Acoustic properties (Figure 26 and Table 12). Calls emitted by a male of *H. nigrovittata* were a single pulsed note of approximately 0.082−0.128 s in duration, and repeated at a rate of 0.09 calls/s, and inter-call intervals were 5.832−16.195 s. Each note comprised of 24−29 pulses, repeated at a rate of 218.75−303.37 pulses/s. Frequency band ranged from 0.35 to 4.80 kHz. The fundamental frequency was 0.69−1.03kHz, with two harmonics. The dominant frequency located on the second harmonic at 0.73−2.76 kHz.

Table 12. Acoustic properties of advertisement calls of *Hylarana nigrovittata.*

Individual	AMNH16928
Number of measured calls	15
Call duration (s)	0.096 ± 0.01 (0.082−0.128)
Inter-call interval (s)	10.764 ± 3.29 (5.832−16.195)
Call repetition rate (calls/s)	0.09
Number of pulses per note	26.40 ± 1.68 (24−29)
Pulse repetition rate (pulses/s)	281.18 ± 23.02 (218.75−303.37)
Frequency band (kHz)	0.41 ± 0.04 4.63 ± 0.09 (0.35−4.80)
Dominant Frequency (kHz)	2.54 ± 0.51 (0.73−2.76)
Fundamental frequency (kHz)	0.78 ± 0.97 (0.69−1.03)

Calling behavior. A calling male was found concealed in a rocky crevice along a small stream in the forest of small hardwoods mixed with bamboo.

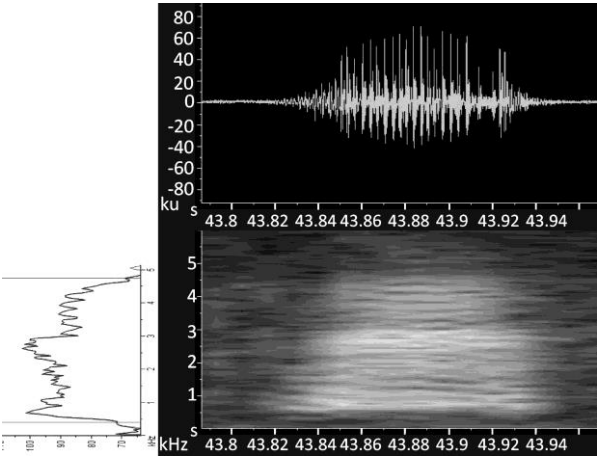

Figure 26. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Hylarana nigrovittata* from SLSM, at a temperature and a humidity of 26.5°C & 85 %, respectively.

4.3. Rhacophoridae

Chiromantis nongkhorensis

A total of 28 calls produced by four males of *Chiromantis nongkhorensis* from the forest of SLSM were analyzed.

Acoustic properties (Figure 27 and Table 13). Calls of this species were comprised of a single, unpulsed note, lasted 0.003−0.018 s, repeated at a rate of 0.02−0.07 calls/s, and inter-call intervals were 0.268−85.905 s. Frequency band was 1.98−17.87 kHz, with three or four clear harmonics. The dominant frequency ranged around 3.83−4.31 kHz, equaled the fundamental frequency or the second harmonic.

The calls differ from the description of Heyer (1971) in duration of 0.003−0.018 s (shorter than that of 0.02−0.03 s in Heyer's description, 1971) and frequency with harmonic structure (versus the lacking of harmonic structure in calls described by Heyer, 1971).

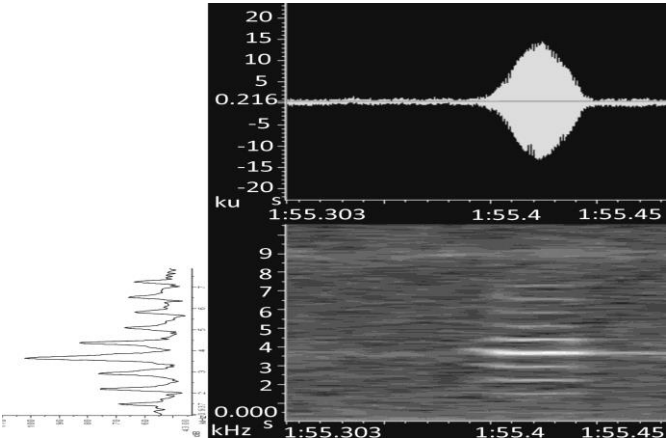

Figure 27. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Chiromantis nongkhorensis* from SLSM, at a temperature of 29.4°C and a humidity of 79.8%.

Table 13. Acoustic properties of advertisement calls of *Chiromantis nongkhorensis*.

Individual	AMNH16917	AMNH16918	AMNH16919	AMNH16916
SVL (mm)	24.69	27.62	27.17	26.09
Temperature (°C)	29.4	29.7	31	29.5
Humidity (%)	80.6	74.8	73.4	86.1
Number of measured calls	3	10	4	11
Call duration (s)	0.015 ± 0.003 (0.012–0.018)	0.004 ± 0.001 (0.004–0.005)	0.003 ± 0.001 (0.003–0.004)	0.005 ± 0.001 (0.004–0.006)
Inter-call interval (s)	29.75 ± 32.19 (6.99–52.51)	20.64 ± 26 (7.45–56.94)	3.38 ± 2.87 (0.35–6.07)	14.76 ± 25.65 (0.268–85.91)
Call repetition rate (call/s)	0.02	0.05	0.03	0.07
Frequency band (kHz)	2.30 ± 0.20 1.39 ± 0.67 (2.08–1.46)	2.23 ± 0.15 14.88 ± 2 (1.99–17.02)	2.06 ± 0.07 17.05 ± 0.19 (1.98–17.22)	2.48 ± 0.20 16.96 ± 2.51 (2.02–17.87)
Dominant frequency (kHz)	4.29 ± 0.02 (4.26–4.31)	4.08 ± 0.99 (3.96–4.13)	3.97 ± 0.95 (3.83–4.04)	4.14 ± 0.05 (4.09–4.26)

Calling behavior. The calling males perched on small shrubs, along a path within the forest, about 1 m above the ground.

Other individuals of this species were also seen calling and perching on grasses in a corn farm nearby the forest of SLSM.

Kurixalus baliogaster

Calls of *Kurixalus baliogaster*, produced by three males from BDNB NP, were recorded at a temperature of 22°C and a relative humidity of 94%.

Acoustic properties (Figure 28 and Table 14). Calls were a trill of continuous pulses of 0.192−0.440 s in duration. Each trill was composed of 13−29 pulses, repeated with a rate of 50.00−76.58 pulses/s. The calls were produced with a long inter-call interval of 0.326−18.418 s and a repetition rate of 0.12−0.54 calls/s. Frequency band ranged from 1.09 to 5.10 kHz. The fundamental frequency was 1.46−1.64 kHz, with one or two unclear harmonics. The dominant frequency was 1.55−2.33 kHz, usually dominated on the fundamental frequency. This is the first description of advertisement call of *K. baliogaster*.

Table 14. Acoustic properties of advertisement calls of *Kurixalus baliogaster.*

Individual	DT0150	DT0155	DT0161
SVL (mm)	32.4	33.6	36.9
Number of measured calls	10	12	6
Call duration (s)	0.381 ± 0.04 (0.302−0.44)	0.255 ± 0.03 (0.216−0.3)	0.240 ± 0.04 (0.192−0.317)
Inter-call interval (s)	8.78 ± 6.09 (0.326−18.418)	7.73 ± 5.33 (0.67−16.55)	8.03 ± 3.57 (3.39−12.54)
Number of pulses per call	25.1 ± 2.77 (20−29)	16.38 ± 2.14 (13−21)	17.67 ± 2.42 (15−22)
Pulse repetition rate (pulses/s)	63.23 ± 1.37 (60.05−64.59)	60.38 ± 4.99 (50.00−66.67)	70.87 ± 4.00 (66.25−76.58)
Frequency band (kHz)	1.26 ± 0.04 4.84 ± 0.1 (1.20−5.04)	1.18 ± 0.08 4.61 ± 0.69 (1.09−5.06)	1.28 ± 0.61 4.90 ± 0.12 (1.20−5.10)
Dominant frequency (kHz)	2.31 ± 0.02 (2.28−2.32)	2.27 ± 0.02 (2.24−2.33)	1.55

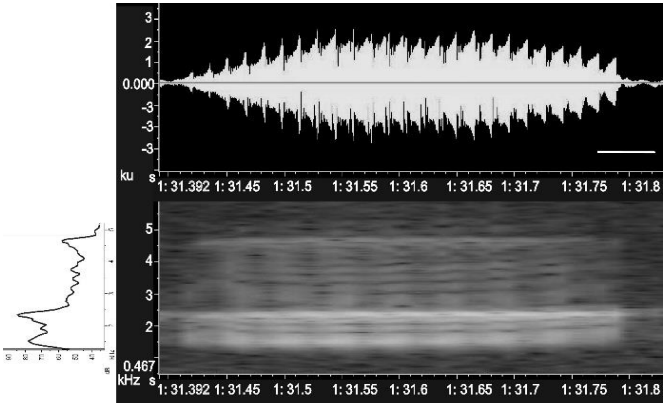

Figure 28. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Kurixalus baliogaster,* from BDNB NP, at a temperature and a humidity of 22°C & 94%, respectively.

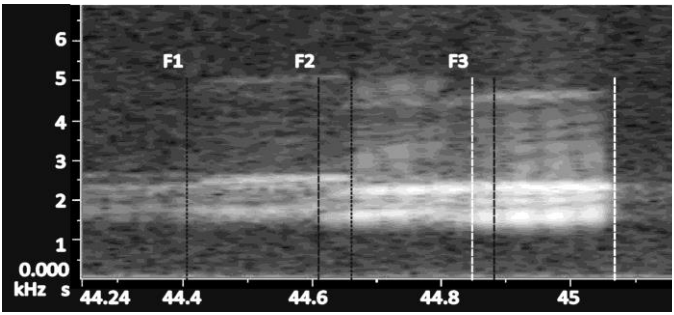

Figure 29. Spectrogram showing synchrony pattern in advertisement calls of *Kurixalus baliogaster* in interaction among three individuals (F1, F2 & F3).

The dash lines are limits of the calls.

Calling behavior. This species has the behavior of congregation for chorus. About ten males were encountered gathering nearby a small stream in the evergreen forest of BDNB NP. The frogs sat on branches of dry shrubs, about 0.3−0.5 m above the ground when conducting the calls. In the chorus, this species performed a pattern of synchrony call. Calls of a male were triggered by audio signals of neighbors, with a short overlap at the beginning of the calls (Figure 29).

Raorchestes gryllus

A total of 24 calls produced by males of *Raorchestes gryllus*, from CYS NP and TD NR were recorded and analyzed. The ambient conditions in which the frogs emitted calls are shown in Table 15.

Table 15. Acoustic properties of advertisement calls of *Raorchestes gryllus.*

Individual	DT0606	DT0747	DT0750
Forest	CYS NP	TD NR	TD NR
SVL (mm)	27.2	26.3	29.1
Temperature (°C)	20	18.8	18.2
Humidity (%)	91.8	99.8	100
Number of measured calls	4	5	15
Call duration (s)	0.457 ± 0.05 (0.395–0.510)	0.423 ± 0.14 (0.262–0.649)	0.785 ± 0.04 (0.708–0.852)
Inter-call interval (s)	2.14 ± 1.67 (0.963–3.317)	1.173 ± 0.44 (0.901–1.682)	1.945 ± 1.58 (0.866–5.515)
Call repetition rate (calls/s)	0.03	0.52 ± 0.19 (0.39–0.66)	0.36
Number of note per call	13.5 ± 1.29 (12–15)	10.6 ± 3.36 (7–16)	17.53 ± 0.83 (16–19)
Note duration (s)	0.011 ± 0.003 (0.002–0.017)	0.016 ± 0.007 (0.006–0.032)	0.005 ± 0.002 (0.002–0.012)
Note repetition rate (notes/s)	27.37 ± 0.36 (27.08–27.85)	22.67 ± 0.37 (22.22–23.11)	21.05 ± 0.38 (19.76–21.33)
Inter-note interval (s)	0.025 ± 0.003 (0.020–0.032)	0.026 ± 0.007 (0.011–0.038)	0.042 ± 0.002 (0.005–0.006)
Frequency band (kHz)	1.17 ± 0.20 1.72 ± 1.12 (0.87–18.34)	1.6 ± 0.26 3.12 ± 0.16 (1.36–3.35)	1.2 ± 0.31 5.87 ± 2.26 (2.21–1.21)
Dominant frequency (kHz)	2.15 ± 0.04 (2.11–2.20)	2.33 ± 0.07 (2.28–2.41)	2.89 ± 0.05 (2.84–2.97)

Acoustic properties (Figure 30 and Table 15). Calls produced by this species were a series of 7–19 unpulsed notes of 0.262–0.852 s in duration, with a call repetition rate 0.03–0.66 calls/s, and inter-call intervals 0.866–5.515 s. The notes were maintained in 0.002–0.032 s, repeated at a rate of 19.76–27.85 notes/s and inter-note intervals were 0.005–0.038 s. Frequency band ranged

from 0.87 to 18.34 kHz. The dominant frequency reached 2.11−2.97 kHz.

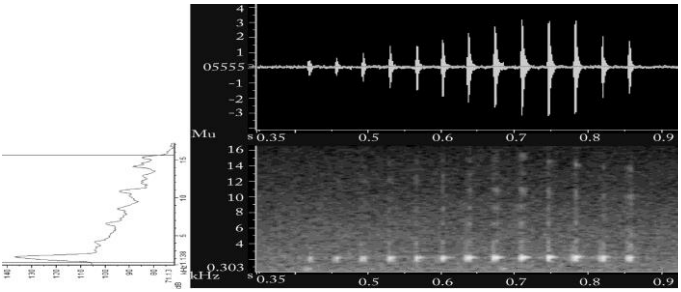

Figure 30. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of a call of *Raorchestes gryllus* from CYS NP, at a temperature and a humidity of 20°C & 91.8%, respectively.

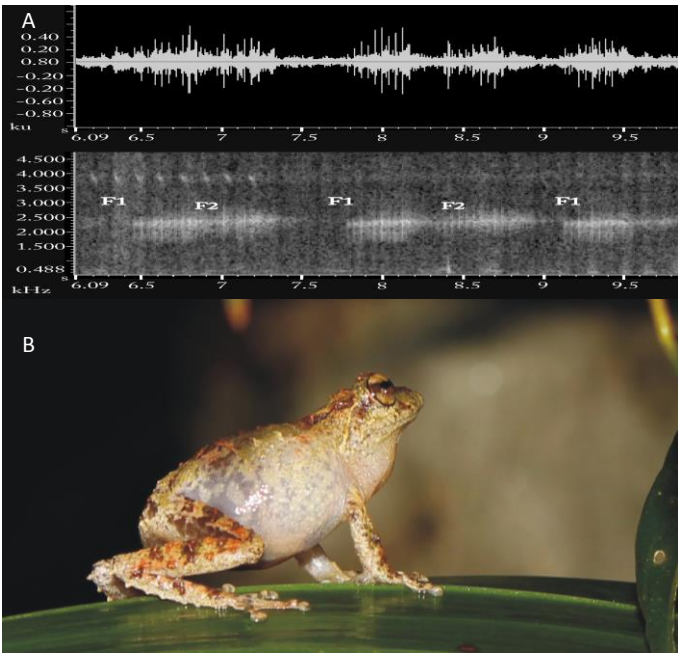

Figure 31. (A) Call alternation pattern in calls of *Raorchestes gryllus;* (B) A calling male of *R. gryllus.*

Calling behavior. Calling males were found standing on leaves of branches of small trees or bushes, about 1.0−1.5 m above the ground. They tended to raise their bodies on four legs when conducting the calls. This species also has the behavior of congregation for chorus at sunset and performed the calls with the pattern of call alternation in chorus (Figure 31).

Rhacophorus annamensis

A total of 56 calls emitted by ten males of *Rhacophorus annamensis* from the forests in CYS NP and TD NR were analyzed. Details related to calling frogs and environmental conditions are listed in Table 16.

Table 16. Body sizes, environmental conditions, and locations of calling *males Rhacophorus annamensis.*

Individual	Call type				Temperature (%)	Humidity (%)	SVL (mm)	Forest
	1	2	3	4				
DT0541	–	–	–	2	23.6	78.2	54.7	CYS NP
DT0542	–	–	–	1	24.0	75.0	57.4	CYS NP
DT0543	–	1	3	2	24.7	74.7	59.5	CYS NP
DT0581	–	–	7	1	22.1	97.4	67.6	CYS NP
DT0585	6	–	13	1	23.6	88.0	59.7	CYS NP
DT0704	–	1	–	1	22.4	91.0	61.1	TD NR
DT0712	1	–	3	–	23.9	85.7	66.6	TD NR
DT0715	1	–	2	–	23.9	85.7	62.5	TD NR
DT0729	2	1	3	2	16.9	100	63.5	TD NR
DT0730	–	–	–	2	21.8	94.1	62.7	TD NR

Acoustic properties (Figure 32). Calls of *Rhacophorus annamensis* were a combination of two types of notes. (1) Note type A was a single, unpulsed note, continued in 0.011−0.039 s. Frequency band of the note ranged from 0.40 to 9.61 kHz, in general, with three clear harmonics. The fundamental frequency, dominated at 0.86−1.88 kHz. The second and third harmonics located at 1.77−1.88 kHz and 2.63−2.81 kHz, respectively. The dominant

frequency equaled the fundamental frequency or the second harmonic. (2) Note type B was a pulsed note of 0.066−0.583 s in duration and was composed of 2.00−25.00 pulses which repeated at rate of 11.70−59.41 pulses/s. Frequency band of the note type B ranged from 0.09 to 6.94 kHz. The calls can be described as four types as follows.

Call type 1 (Table 17). Calls were a single note of type A approximately 0.015−0.038 s in duration. Band of frequencies ranged from 0.40 to 9.35 kHz. The dominant frequency equaled to fundamental frequency at 0.94−1.89 kHz.

Call type 2 (Table 18). Calls were a series of four to nine of notes type A, continued in a duration of 0.437−1.124 s. The notes repeated at a rate of 6.87−8.04 notes/s. Intervals between notes varied from 0.092 to 0.123 s. Frequency band ranged from 0.42 to 9.35 kHz. The dominant frequency equaled the fundamental frequency or the second harmonic, at 1.41−1.81 kHz.

Call type 3 (Table 19). Calls were composed of 1−9 notes type B, maintained in 0.082−4.120 s, repeated at a rate of 0.37−2.17 notes/s and intervals were 0.101−0.382 s. Band of frequencies ranged from 0.07 to 4.26 kHz. The dominant frequencies were 0.75−2.97 kHz.

Call type 4 (Table 20). Calls were broadcasted in a period of 0.394−1.377 s, started with a note type B and followed by a series of one to nine, usually four or five, notes type A. The first group lasted was 0.042−0.250 s in duration, the second group maintained in 0.126−1.138 s, and separated from the first group a period of 0.102−0.137 s. Notes within the second group were delivered at a repetition rate of 3.96−9.10 notes/s. Inter-note intervals were 0.094−0.127 s. Frequency band of the call ranged from 0.36 to 8.38 kHz. The dominant frequency was 1.22−2.06 kHz, in general, located at the second harmonic.

Variation. There was no significant difference in vocal characters between calls type 3 of males in CYS NP and those of males in TD NR. Calls type 4 of males in TD NR had longer call durations 1.040 ± 0.148 s, t (4.17) = 0.6, p = 0.04 and longer durations of the

second group 0.756 ± 0.11 s, t (5.99) = 2.8, p = 0.03 than those of calls of males in CYS NP (0.718 ± 0.14 s and 0.462 ± 0.19 s, respectively).

Calling behavior. Calling males were often found sitting on branches of small trees that were hanging over a pond or shallow water, at least 1 m above the ground. The smallest distance between two calling males was about 2.0−2.5 m.

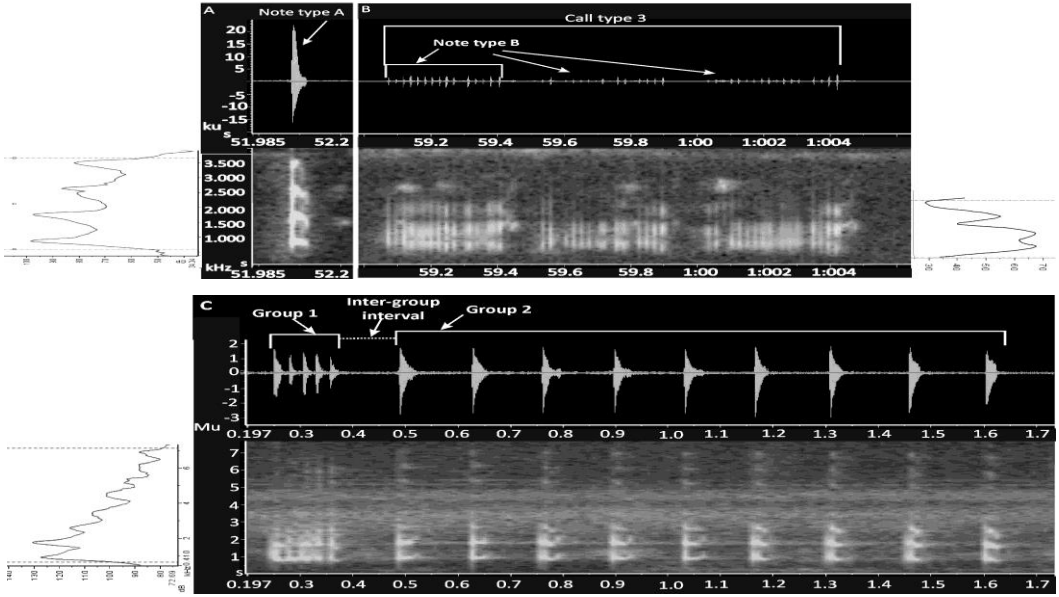

Figure 32. Oscillograms (above), spectrograms and power spectra (below) of the calls of *Rhacophorus annamensis* from TD NR, at a temperature of 19ºC and a humidity of 94%.

(A) Call type 1 composed of one note type A. (B) Call type 3, composed of three notes type B. (C) Call type 4, composed of one note type B and nine notes type A.

Table 17. Acoustic properties of advertisement calls type 1 and type 2 of *Rhacophorus annamensis*.

Individuals	DT0585	DT0712	DT0715	DT0729	DT0543	DT0704	DT0729
Type of call	1	1	1	1	2	2	2
Number of measured calls	6	1	1	2	1	1	1
Call duration (s)	0.022 ± 0.05 (0.015–0.030)	0.019	0.038	0.033 ± 0.06 (0.029–0.037)	0.437	1.124	0.497
Number of note type A per call	1	1	1	1	5	9	4
Note duration type A (s)	0.022 ± 0.05 (0.015–0.030)	0.019	0.038	33.00 ± 5.66 (0.029–0.037)	0.019 ± 0.002 (0.016–0.021)	0.022 ± 0.01 (0.014–0.029)	0.031 ± 0.01 (0.018–0.038)
Note type A repetition rate (notes/s)	–	–	–	–	8.04	7.12	6.87
Inter-note interval (note type A) (s)	–	–	–	–	0.100 ± 0.001 (0.100–0.101)	0.116 ± 0.01 (0.104–0.123)	0.104 ± 0.01 (0.092–0.113)
Frequency band (kHz)	0.97 ± 0.48 3.29 ± 1.70 (0.40–5.83)	1.48–6.12	0.61–4.61	0.74 ± 0.10 3.81 ± 0.20 (0.67–3.95)	0.99–1.60	0.42–4.74	0.62–9.35
Dominant frequency (kHz)	1.63 ± 0.35 (0.94–1.88)	1.89	1.76	1.63 ±0.35 (0.94–1.88)	1.41	1.72	1.81
Fundamental frequency (kHz)	1.33 ± 0.44 (0.94–1.88)	–	0.90	0.88 ±0.30 (0.86–0.90)	1.41	904.40	–

Table 18. Acoustic properties of advertisement calls type 3 of *Rhacophorus annamensis*.

Individuals	DT0543	DT0581	DT0585	DT0712	DT0715	DT0729
Type of call	3	3	3	3	3	3
Number of measured calls	3	7	13	3	2	3
Call duration (s)	1.798 ± 0.85 (1.187–2.770)	1.025 ± 1.03 (0.259–3.047)	2.197 ± 1.44 (0.082–4.123)	1.734 ± 1.06 (0.966–2.944)	1.880 ± 2.35 (0.218–3.542)	2.246 ± 2.00 (0.167–4.145)
Number of note type B per call	4.00 ± 1.73 (3–6)	2.29 ± 0.98 (1–6)	4.85 ± 2.73 (1–9)	4.00 ± 2.65 (2–7)	4.50 ± 4.95 (1–8)	4.33 ± 3.05 (1–7)
Duration of note type B (s)	0.203 ± 0.118 (0.066–0.531)	0.332 ± 0.12 (0.082–0.554)	0.35 ± 0.08 (0.082–4.120)	0.350 ± 0.09 (0.230–0.580)	0.333 ± 0.04 (0.247–0.423)	0.480 ± 0.08 (0.370–0.575)
Note type B repetition rate (notes/s)	1.63 ± 0.21 (1.39–1.81)	0.67 ± 0.84 (1.39–1.66)	1.45 ± 0.69 (1.21–2.17)	1.54 ± 0.50 (1.04–2.04)	1.98 –	0.47 ± 0.08 (0.37–0.58)
Inter-note interval (note type B) (s)	0.275 ± 0.07 (0.201–0.382)	0.13 ± 0.01 (0.114–0.159)	0.141 ± 0.03 (0.119–0.213)	0.115 ± 0.01 (0.101–0.133)	0.114 ± 0.01 (0.105–0.126)	0.145 ± 0.03 (0.124–0.224)
Number of pulses per note	8.08 ± 2.47 (4–13)	12.10 ± 4.02 (4–19)	15.00 ± 4.05 (4–25)	13.67 ± 0.70 (10–21)	14.33 ± 2.78 (10–18)	16.46 ± 3.95 (8–24)
Pulse repetition rate (pulses/s)	39.51 ± 10.31 (11.30–55.56)	33.85 ± 5.35 (23.53–41.92)	40.12 ± 7.95 (33.54–50)	36.52 ± 4.89 (28.25–43.59)	40.73 ± 2.92 (35.46–44.53)	38.38 ± 6.43 (27.83–53.74)
Frequency band (kHz)	0.67 ± 0.04 1.38 ± 0.02 (0.50–1.39)	0.51 ± 0.08 2.14 ± 0.45 (0.41–2.62)	0.40 ± 0.10 2.33 ± 0.30 (0.07–3.11)	0.61 ± 0.05 2.96 ± 0.92 (0.55–3.86)	0.49 ± 0.11 3.64 ± 0.87 (0.42–4.26)	0.39 ± 0.17 2.87 ± 0.08 (0.20–2.97)
Dominant frequency (kHz)	1.03 –	1.17 ± 0.26 (0.75–1.41)	1.22 ± 0.26 (0.75–1.5)	1.68 ± 0.45 (1.25–2.15)	0.86 ± 0.12 (0.78–0.95)	1.94 ± 0.89 (1.42–2.97)

Table 19. Acoustic properties of advertisement calls type 4 of *Rhacophorus annamensis*.

Individuals	DT0541	DT0542	DT0543	DT0581	DT0585	DT0704	DT0729	DT0730
Type of call	4	4	4	4	4	4	4	4
Number of measured calls	2	1	2	1	1	1	2	2
Call duration (s)	0.680 ± 0.06 (0.638–0.722)	0.919	0.540 ± 0.07 (0.496–0.589)	0.782	0.671 ± 0.16 (0.560–0.782)	1.181	0.886 ± 0.7 (0.394–1.377)	1.052 ± 0.09 (0.989–1.115)
Number of note type B per call	1	1	1	1	1	1	1	1
Duration of the group 1 (or duration of note type B) (s)	0.144 ± 0.05 (0.111–0.177)	0.042	0.105 ± 0.01 (0.097–0.112)	0.130	0.163	0.211	0.185 ± 0.09 (0.120–0.250)	0.108 ± 0.06 (0.065–0.105)
Number of pulses per note	7.0 ± 1.41 (6–8)	2	5.5 ± 0.71 (5–6)	6	7	9	8.0 ± 4.24 (5–11)	4.5 ± 3.5 (2–7)
Pulse repetition rate (pulses/s)	42.29 ± 3.88 (39.55–45.05)	23.81	42.94 ± 2.41 (41.24–44.64)	38.46	36.81	37.92	36.67 ± 4.71 (33.33–40.00)	27.69 ± 17.41 (15.38–40.00)
Inter-group interval (s)	0.122 ± 0.018 (0.109–0.134)	0.102	0.121 ± 0.04 (0.118–0.123)	0.126	0.111	0.137	0.123 ± 0.005 (0.119–0.126)	0.142 ± 0.15 (0.132–0.152)
Duration of group 2 (s)	0.415 ± 0.01 (0.411–0.418)	0.756	0.318 ± 0.08 (0.261–0.374)	0.536	0.286	0.833	0.632 ± 0.72 (0.126–1.138)	0.802 ± 0.01 (0.792–0.813)
Number of note type A per call	4 –	7	3.5 ± 0.71 (3–4)	5	3	7	5.0 ± 5.66 (1–9)	6 –
Duration of note type A (s)	0.020 ± 0.003 (0.016–0.026)	0.022 ± 0.004 (0.015–0.027)	0.014 ± 0.002 (0.011–0.018)	0.020 ± 0.008 (0.014–0.034)	0.028 ± 0.008 (0.020–0.035)	0.030 ± 0.007 (0.020–0.039)	0.030 ± 0.007 (0.018–0.039)	0.027 ± 0.004 (0.018–0.033)
Note type A repetition rate (notes/s)	7.24 ± 0.09 (7.18–7.30)	7.94	7.84 ± 0.25 (7.66–8.02)	7.46	6.99	7.20	9.10	5.06 ± 1.55 (3.96–6.15)
Inter-note interval (note type A) (s)	0.112 ± 0.01 (0.101–0.127)	0.100 ± 0.007 (0.094–0.114)	0.107 ± 0.002 (0.105–0.110)	0.110 ± 0.01 (0.094–0.121)	0.102 ± 0.008 (0.096–0.107)	0.104 ± 0.004 (0.099–0.110)	0.107 ± 0.01 (0.096–0.125)	0.128 ± 0.01 (0.120–0.160)
Frequency band (kHz)	0.36 ± 0.03 3.79 ± 0.14 (0.62–3.89)	0.71–8.25	0.77 ± 0.07 2.46 ± 0.54 (0.72–2.85)	0.44–8.38	3.17–0.41	0.59–7.13	0.47 ± 0.16 5.87 ± 3.30 (0.36–8.20)	0.64 ± 0.07 6.62 ± 2.65 (0.58–6.80)
Dominant frequency (kHz)	1.88	2.06	1.27 ± 0.07 (1.22–1.31)	1.88	1.88	1.77	1.68 ± 0.12 (1.59–1.77)	1.83 ± 0.15 (1.72–1.94)

Rhacophorus calcaneus

A total of eight calls, produced by five males of *Rhacophorus calcaneus* from BDNB NP and CYS NP, were recorded at ambient conditions of 19°C & 94% and 20°C & 91.8% for each site, respectively.

Acoustic properties (Figure 33 and Table 20). Calls of this species were 4.353−6.337 s in length, repeated with an interval of 168.413 s. The calls were composed of two groups. The first group was a long trill of 31−51 pulses, maintained in duration of 2.306−4.095 s and emitted at a repetition rate of 10.74−13.96 pulses/s. The second group was composed of 1−6 short pulsed notes, separated from the first group a period of 0.277−1.089 s, and lasted for 0.078−2.605 s. Each note continued in duration of 0.020−0.166 s and reoccurred at a rate of 0.86−1.75 notes/s. Each note contained 2−7 pulses, generated at a rate of 18.69−35.71 pulses/s. Frequency band ranged from 0.36 to 5.58 kHz. The dominant frequency reached 1.23−1.55 kHz.

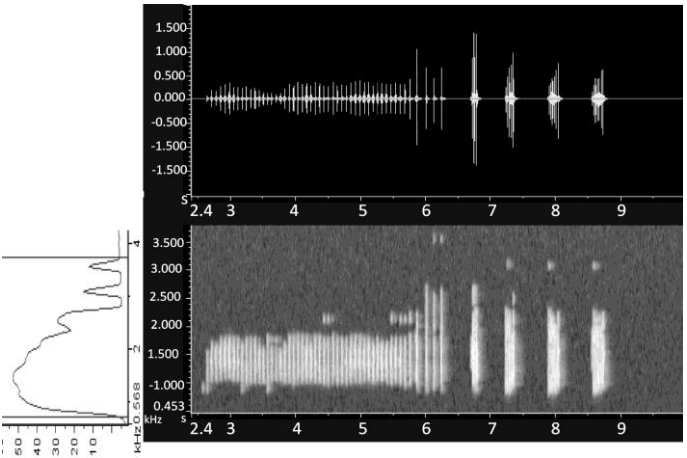

Figure 33. Oscillogram (above), spectrogram (below, right), and power spectrum (below, left) of the call of *Rhacophorus calcaneus* from BDNB NP, at a temperature and humidity of 19°C & 94%, respectively.

Table 20. Acoustic properties of advertisement calls of *Rhacophorus calcaneus*.

Individual	DT0502	DT0503	DT0504	DT0506	DT0607
Forest	BDNB NP	BDNB NP	BDNB NP	BDNB NP	CYS NP
SVL (mm)	35.8	36.3	39.2	37.1	43.6
Temperature (°C)	19	19	19	19	20
Humidity (%)	94	94	94	94	91.8
Number of measured calls	2	1	2	2	1
Call duration (s)	6.209 ± 0.18 (6.081–6.337)	6.102	4.515 ± 0.23 (4.353–4.676)	4.856 ± 0.57 (4.455–5.257)	6.033
Group 1 duration (s)	3.314 ± 0.13 (3.220–3.407)	3.608	3.229 ± 0.06 (3.186–3.271)	2.306 ± 0.22 (2.462–2.149)	4.095
Number of pulse in group 1	43	51	42 ± 1.41 (41–43)	33 ± 2.83 (31–35)	45
Pulse repetition rate in group 1 (pulses/s)	12.69 ± 0.51 (12.38–13.04)	13.86	12.71 ± 0.67 (12.23–13.18)	13.88 ± 0.11 (13.81–13.96)	10.74
Inter-group interval (s)	0.746 ± 0.19 (0.609–0.882)	0.465	0.836 ± 0.19 (1.089–0.582)	0.391 ± 0.19 (0.277–0.504)	0.781
Duration of group 2 (s)	2.150 ± 0.24 (1.979–2.321)	2.029	0.451 ± 0.53 (0.078–0.823)	2.160 ± 0.62 (1.716–2.605)	1.157
Number of note in group 2	4	4	1.5 (1–2)	4.5 (5–6)	2
Duration of note in group 2 (s)	0.020	0.140	0.060	0.020	0.166
Note repetition rate in group 2 (notes/s)	1.40 ± 0.16 (1.29–1.52)	–	1.22	1.64 ± 0.15 (1.54–1.75)	0.86
Inter-note interval in group 2 (s)	0.596 ± 0.08 (0.545–0.701)	0.492	0.532	0.518 ± 0.24 (0.199–0.720)	0.826
Number of pulses in group 2	3.89 ± 0.78 (3–5)	5.33 ± 2.08 (3–7)	4.75 ± 1.53 (3–6)	3.00 ± 0.70 (2–4)	5.50 ±0.70 (5–6)
Pulse repetition rate in groups 2 (pulses/s)	29.49 ± 1.34 (26.67–31.25)	29.49 ± 8.80 (19.41–35.71)	26.99 ± 2.18 (25.64–29.70)	26.28 ±4.45 (18.69–32.26)	27.12 ± 1.14 (26.32–27.93)
Frequency band (kHz)	0.77 ± 0.04 5.37 ± 0.31 (0.75–5.58)	0.71–3.73	0.47 ± 0.16 3.99 ± 0.77 (0.36–4.54)	0.85 ± 0.01 4.51 ± 0.08 (0.57–4.45)	0.39–1.19
Dominant frequency (kHz)	1.49 ± 0.09 (1.42–1.55)	1.51	1.41 ± 0.38 (1.23–1.25)	1.45 ± 0.07 (1.41–1.5)	1.50

Calling behavior. Calling males were found sitting on branches of small trees, away from the streams (up to 5 m), in the forests. The smallest distance between two calling individuals was about 2 m. This species is quite sensitive for surrounding disturbances such as light or sounds. The calling individuals could keep silence a long time when they recognized disturbances.

CHAPTER IV. DISCUSSION

1. Taxonomic problems and species complexes

1.1. *Brachytarsophrys intermedia*

Rao and Yang (Rao & Yang, 1997) considered *Brachytarsophrys intermedia* as synonym of *B. carinense* (Boulenger, 1889). Data for this work was based on only two figures that the two species share: tropical climate zone and presence of a pair of long, oblique glandular folds on dorsum. The evidence seems not strong enough to assign these species as synonym. Based on the field data and examined specimens in this study, descriptions of *B. intermedia* written by Smith (1921) and Bourret (1942), and description of *B. carinense* by Taylor (1962), *B. intermedia* can be distinguished from *B. carinense* by having the following characters: (1) tongue free for 0.32−0.46 times of its length (versus tongue free for at least half of its length in *B. carinense*); (2) length of vomerine teeth row 0.47−0.63 times distance between them (versus lengths of the vomerine teeth groups about 0.25 times of distance between them in *B. carinense*); (3) fold or ridge on tarsus absent (versus a thickened rounded ridge on tarsus in *B. carinense*); (4) interorbital region with a thin dark brown cross-bar without row of spots between anterior part of eye (versus a series of small light spots, crossing between anterior part of eye and a continuous line crossing between middle of eyelid in *B. carinense*); (5) cross-bars on limbs clear, dorsal surface of thigh without pair of outer diagonal yellowish spots (versus dark bars on limbs indistinct but pair of outer diagonal yellowish spots present on dorsal of thigh in *B. carinense*); and (6) these frogs also have different behaviors in calling that are mentioned in bioacoustic discussion.

1.2. *Hylarana nigrovittata* complex

There were pieces of evidence, both in tadpoles and adult individuals, indicating that *H. nigrovittata* is a complex species. Based on molecular analyses, two groups within the *H. nigrovittata* in Thailand were recognized (Matsui et al., 2001). By morphological analyses, Ohler et al. (2002) suggested there were five groups of *H.*

nigrovittata within Thailand and the Indochine subregion. Gawor et al. (2011) showed differences in morphology of tadpoles as well as of adults between populations from Thailand and Vietnam. The differences in morphological characters of specimens of *H. nigrovittata* from the Langbian Plateau in comparison with other populations are not clear but they have different advertisement calls in comparison with those of males from Quang Binh Province (see in bioacoustics part). Hence, the connection among these traits is still unclear and needs to be clarified in further studies.

1.3. *Polypedates leucomystax* complex

Based on molecular analyses, *Polypedates leucomystax* complex in Vietnam was assigned as *P. megacephalus* and *P.* cf*. mutus* (Kuraishi et al., 2013). The authors also provide evidence for two different groups of *P. mutus* in south of China and Laos without mentioned morphological diagnosis for these groups except for the lacking of vocal sac in males. The *P.* cf. *mutus* from Kon Tum, Vietnam was considered belonging to the group occurring in the south of China (Kuraishi et al., 2013).

P. mutus differs from *P. megacephalus* in morphology mainly based on the absence of the vocal sac in males (Smith, 1940; Inger et al., 1999; Kuraishi et al., 2013). Kuraishi et al (2012) and Inger et al., (1999) also suggested that *P. mutus* could be distinguished from *P. megacephalus* by two other characters: (1) the presence of dorsal stripes and (2) width of disc on the third finger larger than tympanum diameter (versus the dorsal stripes absent and width of disc on the third finger narrower than tympanum diameter in males of *P. megacephalus* in the description of Inger et al., 1999).

However, in the original description, Smith (1940) described *P. mutus* with three types of dorsal texture pattern: uniform or scattered with small black spots or with four dark brown stripes. Taylor (1962) also figured out the presence of four dorsal stripes as one of diagnostic character for *Rhacophorus leucomystax sexvirgatus*, synonym of *P. leucomystax* (Kuraishi et al., 2013).

Furthermore, the specimens from the Langbian Plateau (DT0377—8, DT0435 & DT991) have the ")(" - shape mark on region posterior of occiput; dorsum with two pairs of longitudinal brown lines; and disc of the third finger 0.2—0.4 times of tympanum diameter. This evidence shows that there is still confusion in morphology of these species.

1.4. *Raorchestes gryllus*

The collection of *Raorchestes gryllus* from the surveys showed a wide spectrum of dorsal color pattern (Plate 13). Both the original description (Smith, 1924) and description by Orlov et al., (2012) mentioned the wide variation of color pattern in life of this species.

The color pattern is formed by alternating of the two background colors, yellow brown and green surround the dark brown, ")(" shape mark and interorbital cross-bar. The yellow brown, varying from light ground to dark brown, is the main background color. The green covers parts of the dorsum and side of head, sometimes, on upper part of flank, mixing together with the yellow brown, with different levels of size and tone of color, and forming different patches on these areas. It maybe disappears or covers completely the entire dorsum and side of head as in pattern of female individuals.

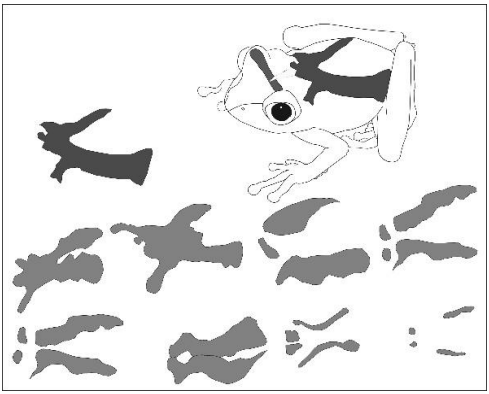

Figure 34. Variation of dorsal texture pattern in *Raorchestes gryllus*

The dark brown, ")(" shape mark is also changeable itself in size, shape (Figure 34), and color (from reddish to dark brown). The interorbital cross-bar varies in level of color, from dark brown to yellow brown and unique to the background color.

Unlike the dorsal color pattern, there is no trace for frame or rule of changing of texture pattern on flanks, especially in region of groin in which small, round spots, or larger blotches, or oblique stripes could be present.

The morphological characters of this species are very similar to those of some other species such as *Kurixalus bisacculus* or *K. banaensis* (IUCN, 2012; Orlov et al., 2012). Morphological diagnosis seems not so strong for the species and taxonomical allocation of *Raorchestes gryllus* needs to be confirmed based on other analytical techniques (Orlov et al., 2012). Furthermore, this species has been recorded in a wide range of habitats, in cloud forests, evergreen forests, and evergreen forests mixed with bamboo forests, at elevations between 815 and 2027 m.

1.5. *Rhacophorus calcaneus* and *Rhacophorus robertingeri*

Based on morphological examination, *Rhacophorus chuyangsinensis* was synonymized with *R. calcaneus* by Orlov et al., (2012). And by the same work, the species considered as "*Rhacophorus calcaneus*" in some reports in the past (e.g. Orlov et al., 2008, Inger et al., 1999) was described as new species R*hacophorus robertingeri* (Orlov et al., 2012). According to the authors (Orlov et al., 2012), *R. robertingeri* differs from *R. calcaneus* mainly in texture and coloration patterns on dorsal surface and flank as follows: (1) dorsal surface of *R. robertingeri* is red-brown (versus the green, bluish, or greyish dorsal surface of *R. calcaneus*) and (2) flank of *R. robertingeri* without two big, black symmetrical spots (versus two large, black spots present on flank of *R. calcaneus*). These features are changeable and difficult to recognize in old specimens because of fainting of color along time.

Another character for distinguishing these two species could be figured out by structure of the toe webbing. The webbing between toes is more developed in *R. robertingeri* than in *R.*

calcaneus ($I_{0-1½}II_{0-1}III_{1-2¼}IV_{½-1}V$ versus $I_{1-2(2¼)}II_{1½-2}III_{1-1½(2)}IV_{1½(2)-1½}V$ in *R. calcaneus*).

2. Bioacoustics

Another aim of this study is linking the morphology and bioacoustics to support for taxonomic identification. Therefore, I compared the advertisement call of morphologically similar species of the families Megophryidae, Ranidae and Rhacophoridae.

2.1. Vocal property and behavior similarities within the anuran families

Megophryidae

Brachytarsophrys intermedia did response to almost the human mimic calls after keeping quiet for a short time, even during the day. This behavior is distinctly different from that of remaining quiet for a long time, about 45 minutes, in *B. carinense* (Taylor, 1962).

Of 14 species of *Leptolalax* recorded in Vietnam, five species (*L. aereus*, *L. applebyi*, *L. bidoupensis*, *L. melicus*, and *L. tuberosus*) have a known advertisement call. Advertisement calls of *L. bidoupensis* presented in this study have the same variation in vocal properties as those described by Rowley et al. (2011b) except the presence of the initial note. Calls of males from BDNB NP, PB NP and SLSM have an unpulsed, initial note which has a little bit longer duration than those of the subsequent notes. The initial note in calls of *L. bidoupensis* in this study is similar to that of calls of *L. melicus* but the note of calls of *L. bidoupensis* was unpulsed in contrast to the pulsed note of calls of *L. melicus* in the description of Rowley et al. (2010d). Durations of the initial note in calls of *L. bidoupensis* (0.061−0.230 s) are longer than those of *L. melicus* (0.058−0.070 s). Furthermore, the dominant frequencies of calls emitted by *L. bidoupensis* (2.38−3.11 kHz) are lower than those of calls produced by *L. melicus* (3.56−3.77 kHz) .

Differences in vocal figures of advertisement calls of the genus *Leptolalax* that have been known from Vietnam are presented in Table 21.

Table 21. Acoustic properties of advertisement calls of *Leptolalax* that are distributed in Vietnam.

Species	*Leptolalax*					
	bidoupensis	*bidoupensis*	*aereus*	*applebyi*	*melicus*	*tuberosus*
Temperature (°C)	12.9–26.4	19.0–21.0	22.4–25.7	21.5	26.1–26.2	22.5–24.5
Call duration (s)	0.091–0.926	0.320–0.479	0.026–0.077	–	0.278–0.292	0.057–0.074
Inter-call interval (s)	1.134–22.160	4.014–9.511	0.085–0.307	–	0.920–1.248	0.002–0.009
Call repetition rate (calls/s)	0.04–0.74	0.10–0.22	2.40–8.00	–	0.70–0.80	0.10–0.50
Number of note(s) per call	2.50–17.10	6.7–8.2	2.95–9.50	–	2.51–2.68	1
Different initial note	present	absent	absent	absent	present	absent
Duration of initial note (s)	0.061–0.230	–	–	–	0.058–0.070	–
Note duration (s)	0.006–0.023	0.006–0.008	3.000–8.300	–	0.007–0.008	–
Note repetition rate (notes/s)	6.53–18	14–21	64–106	–	–	–
Inter-note interval (s)	0.034–0.121	0.049–0.056	–	–	–	–
Number of pulses in initial note	–	–	–	–	1.2	–
Pulse in initial note repetition rate (pulse/s)	–	–	–	–	23–24	–
Number of pulses per note	–	–	–	–	22.7–26.5	–
Pulse repetition rate (pulses/s)	–	–	–	–	363–394	–
Dominant Frequency (kHz)	2.38–3.11	2.0–2.5	6.34–7.26	3.96–4.31	3.56–3.77	2.61–2.76
References	This study	Rowley et al., 2011b	Rowley et al., 2010c	Rowley et al., 2010c	Rowley et al., 2010d	Rowley et al., 2010a

Advertisement calls of *Xenophrys major* differ from calls of *X. major* from Quang Binh Province, described by Ziegler (2002) under the name *X. lateralis* (synonym of *X. major* by Orlov et al., 2002), in the following figures: calls with “mono-type” (versus calls

with multi-type); number of notes within a group or call 9−26 (versus number of the “one-pulse group” is five); average note duration of 0.101−0.144 s (longer than that of the “one-pulse group”: 0.076−0.095 s); average note repetition rate 1.67−3.81 notes/s (slower than the repetition rate of the “one-pulse group” 5 calls/s). However, calls of the both frogs shared a similar range of dominant frequencies (*X. major* from SLSM: 2.21−2.51 kHz and *X. major* from Quang Binh Province: 2.6 kHz) and a pattern of intensity of note or the “one-pulse group” in which the intensity rapidly reaches the peak and gradually decrease toward the end (Figure 35).

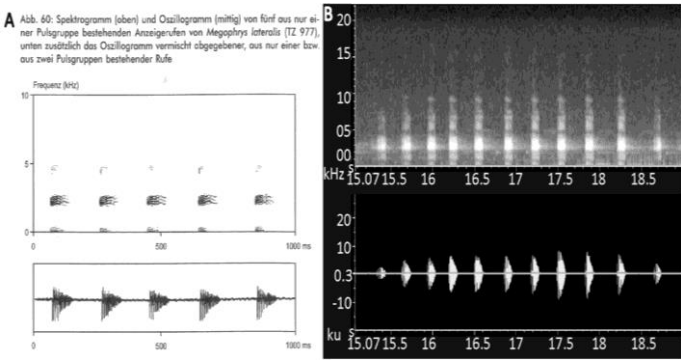

Figure 35. Advertisement calls of *Xenophrys major*; (A) record from Quang Binh Province (Ziegler, 2002); (B) record from SLSM.

Calls of the both frogs were analyzed with 256, Hann window FFT.

Ranidae

The advertisement calls of *Hylarana nigrovittata* presented in this study with a duration of 0.096 ± 0.01 s, were similar to those of *H. nigrovittata* (0.097 ± 0.004 s), from Quang Binh Province, Vietnam (Ziegler, 2002). However, the calls emitted by males from SLSM differed from those recorded from Quang Binh Province in the following figures: call with single note; number of pulses per note 26.40 ± 1.68; rate of call repetition 0.09 calls/s; and the dominant frequency of 2.54 ± 0.51 kHz (versus the calls of two pulsed notes,

separated by a gap of 0.006−0.008 s; number of pulses in the first note was 18−21; rate of call repetition was 0.13 calls/s; and the dominant frequency was 3.1 kHz in the description by Ziegler, 2002).

The calls of *H. nigrovittata* from SLSM were similar to calls of *H. nigrovittata* from Thailand (Heyer, 1971) in structure of one pulsed note and frequency with harmonics, but differed from calls of Thailand *H. nigrovittata* in call duration 0.082−0.128 s; number of pulses per note 24−29; and the dominant frequency 0.73−2.76 kHz (versus duration: 0.160−0.210 s; number of pulses per note 2−4; and the dominant frequency 0.90−1.50 kHz in the description of Heyer, 1971).

Differences could be due to differences of ambient conditions in which these recordings were conducted (calls of males from SLSM were recorded at a temperature 26.5^{o}C and a relative humidity of 85 % while calls of males from Quang Binh Province were recorded at 25^{o}C and a relative humidity of 79%; ambient conditions of the recording from Thailand were unknown). These factors could affect the vocal properties such as dominant frequency, call duration, call repetition rate, pulse duration, pulses repetition rate (Gerhardt & Huber, 2002). However, data from this study are not sufficient to understand the environment influences concerning these vocal features.

Difference in the bioacoustics analyzed (calls presented in this study were analyzed with Hann window, 1024 samples while calls in Ziegler's (2002) description were performed with Hann window, 256 samples, and calls in the description of Heyer (1971) analyzed by a Kay Electrics Sonagraph Model 6061B, using 0.08−8.00 kHz) could contribute to change the dominant frequency but did not make the calls different in structure (Figure 36). Thus, the difference in number of notes of calls between this study and the description of Ziegler (2002) is not caused by the analysis methods.

Another reason could be that *H. nigrovittata* is a complex of sibling species (Matsui et al., 2001, Ohler et al., 2002, Gawor et al., 2009; Frost, 2013) and that the differences in these calls could

be traits of different species. Data of these three populations need to be confirmed in morphological and molecular features.

The results of this study provide for the first time descriptions of advertisement calls of *H. attigua* and *H. milleti.* Differences in vocal characters give more evidence for distinguishing these two very morphologically similar species.

Calls of both species have only one note and share a similar range of dominant frequency, from around 2.17 to 3.09 kHz. *H. attigua* could produce two types of calls while *H. milleti* exhibited only one type of call.

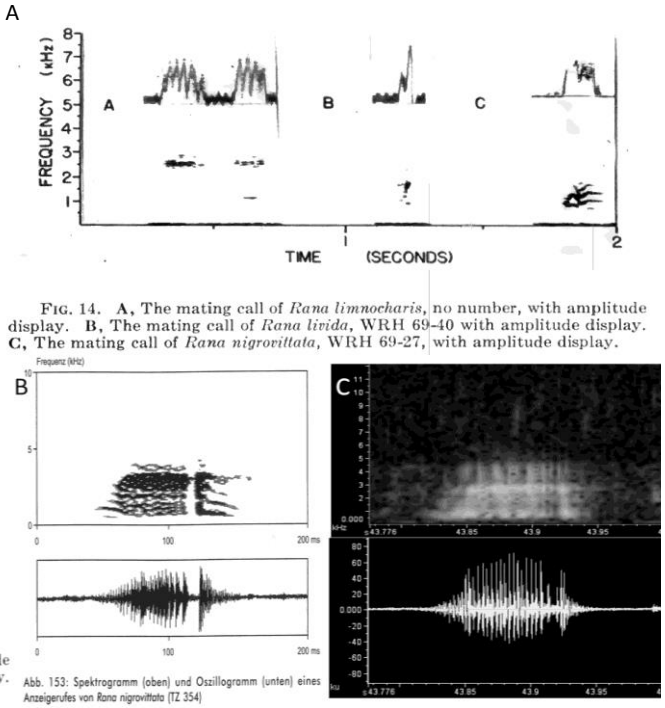

FIG. 14. **A**, The mating call of *Rana limnocharis*, no number, with amplitude display. **B**, The mating call of *Rana livida*, WRH 69-40 with amplitude display. **C**, The mating call of *Rana nigrovittata*, WRH 69-27, with amplitude display.

Abb. 153: Spektrogramm (oben) und Oszillogramm (unten) eines Anzeigerufes von *Rana nigrovittata* (TZ 354)

Figure 36. Advertisement calls of *Hylarana nigrovittata.*

(A) Call recorded from Thailand (Heyer, 1971). (B) Call recorded from Quang Binh Province, Vietnam (Ziegler, 2002). (C) Call recorded from SLSM, Vietnam (in this study). Both the spectrograms in B & C are performed with Hann window, 256.

Calls type 1 of *H. attigua* are distinctly different from calls of *H. milleti* with a longer duration (0.228−0.366 s); a higher number of pulses per note (87.40−117.36); and a higher rate of pulse repetition (316.75−417.62 pulses/s) than those of *H. milleti* (call duration: 0.053−0.082 s; number of pulses per note: 14.80−23.10; and pulse repetition rate: 256.35−322.63 pulses/s).

Calls of *H. milleti* are more similar to those of *H. attigua* in type 2 than in type 1. However, the call type 2 of *H. attigua* is still distinguished from the call of *H. milleti* by having a call duration 0.035−0.037 s and a number of 9.20−12.50 pulses per note (versus the call of *H. milleti* with a longer call duration: 0.053−0.082 s and a higher number of pulses per note: 14.80−23.10).

Advertisement calls of all the three species *H. attigua*, *H. milleti*, and *H. nigrovittata* are a single pulsed note. Differences in acoustic properties of advertisement calls among these three species and other species of the genus *Hylarana* are presented in Table 22.

Table 22. Acoustic properties of advertisement calls of genus *Hylarana*.
(QB: recorded from Quang Binh Province, Vietnam; TL: recorded from Thailand).

Species	*Hylarana*		
	attigua	*attigua*	*milleti*
Temperature (°C)	23.4–26.5	23.4–26.5	20.4–23.4
Humidity (%)	100	100	77–100
Type	1	2	–
Call duration (s)	0.228–0.366	0.035–0.037	0.053–0.082
Inter-call interval (s)	3.940–30.488	5.650–5.910	0.059–2.380
Call repetition rate (calls/s)	0.03–0.19	–	0.4–1.52
Number of note(s) per call	1	1	1
Note repetition rate (notes/s)	–	–	–
Number of pulses per note	87.40–117.36	9.20–12.50	14.80–23.10
Pulse repetition rate (pulses/s)	316.75–417.62	245.48–312.46	256.35–322.63
Dominant Frequency (kHz)	2.49–2.82	2.43–2.56	2.17–3.09
References	This study	This study	This study

Table 22. Acoustic properties of advertisement calls of genus *Hylarana* (continued).

Species	*Hylarana*								
	nigrovittata			*baramica*	*glandulosa*	*guentheri*	*luctuosa*	*picturata*	*signata*
	(SLSM)	(QB)	(TL)						
Temperature (°C)	26.5	25.5	–	–	–	27	–	–	–
Humidity (%)	85	79	–	–	–	83	–	–	–
Type	–	–	–						
Call duration (s)	0.096± 0.01 (0.082–0.128)	0.098 ± 0.004	0.160–0.210	3.500	–	0.104–0.117	–	–	–
Inter-call interval (s)	10.764	–	–	–	0.57	–	–	–	–
Call repetition rate (calls/s)	–	–	–	–	–	0.13	–	–	–
Number of note(s) per call	1	2	1	10	1	–	1	2–3	6
Note repetition rate (notes/s)	–	–	–	0.13	0.57	–	0.05	0.23	0.03
Number of pulses per note	26.40 (24–29)	–	3.00–4.00	–	–	–	–	–	–
Pulse repetition rate (pulses/s)	281.18	–	–	–	–	–	1	2–3	–
Dominant Frequency (kHz)	2.54	3.1	0.90–1.50	2.0–2.8	1.0–2.0	0.4	1.0–2.0	2.0–3.0	2.0–4.0
References	This study	Ziegler, 2002	Heyer, 1971	Zainudin et al., 2010	Zainudin et al., 2010	Ziegler, 2002	Zainudin et al., 2010	Zainudin et al., 2010	Zainudin et al., 2010

Rhacophoridae

Calls of *Kurixalus baliogaster* are similar to those of *K. bisacculus* (*K. verrucosus* synonymized by Yu et al., 2013) with the structure of a single trill of continuous pulses. *K. baliogaster* also has the behavior of calling in groups and to perform a pattern of synchrony call like *K. bisacculus* (Ziegler, 2002).

The calls of *K. baliogaster* differ from those of *K. bisacculus*, recorded from Quang Binh Province, Vietnam, at condition of 26^{o}C and 71% relative humidity (Ziegler, 2002) by having a longer average duration 0.240−0.381s; higher average call repetition rate 7.73−8.78 calls/s; fewer number of pulses per note 16.38−25.1; slower pulse repetition rate on average of 60.38−70.87 pulses/s; broader frequency band from 1.18 to 4.90 kHz; and higher average dominant frequency 1.55−2.31 kHz (versus calls of *K. bisacculus* with a duration 199.8 ± 0.02 s; call repetition rate 2.5 calls/s; number of pulses per note 27.00 ± 2.20; pulse repetition rate 141.50 ± 2.40 pulses/s; band of frequencies 1.30−1.80 kHz; and the dominant frequency 1.7 Hz. The frequencies were measured with FFT-Hann window 256, Ziegler, 2002).

The calls of *K. baliogaster* are also similar to those of *K. appendiculatus* under the name of *Rhacophorus appendiculatus* (synonymized by Yu et al., 2013), from Thailand (Heyer, 1971) in the structure of one pulsed note and the range of dominant frequency between 1.55 and 2.50 kHz (*Kurixalus baliogaster*: 1.55−2.31 kHz and *K. appendiculatus*: 1.60−2.50 kHz). Differences between calls of these two species are: call duration (*K. baliogaster*: 0.240−0.381 s versus *K. appendiculatus*: 0.048 s); number of pulses within a call (*K. baliogaster*: 16.38−25.10 versus *K. appendiculatus*: 3−4); and harmonic structure (*K. baliogaster*: present versus *K. appendiculatus*: absent).

Advertisement calls of *Raorchestes gryllus* are described here for the first time, a long time after this frog was discovered (Smith,

1924). In comparison with descriptions of calls generated by two other species *R. graminirupes* (Bee et al., 2013) and *R. parvulus* with the synonym name of *Philautus parvulus* (Heyer, 1971), that also have their distributions in Vietnam, there are differences in many vocal properties among these species.

Calls of *Raorchestes gryllus* have a large overlap in range of dominant frequency with those of calls of *R. graminirupes*, from the Western Ghats of India (Bee et al., 2013), the dominant frequency of calls of *R. gryllus* locates at 2.15−2.89 kHz and those of calls of *R. graminirupes* range from 2.4 to 3.1 kHz. Calls of both species also share a similar duration of note (*R. gryllus*: 0.005−0.016 s and *R. graminirupes*: call type 1: 0.006 ± 0.01 s & call type 2: 0.007 ± 0.01 s). Calls of *R. gryllus* differ from those of *R. graminirupes* by having: mono-type of call; duration 0.423−0.785 s; number of notes within a call 7−19; and note repetition rate 21.05−27.37 notes/s (versus calls with two different types; durations of call type 1: 0.083 s & call type 2: 0.026 ± 0.003 s; number of pulses per call type 1: 3−22 & call type 2: 2−7; pulse repetition rate of call type 1: 154.7 ± 19.5 pulses/s & call type 2: 155.8 ± 18.6 pulses/s in the description of Bee et al., 2013).

Although calls of the two species *R. gryllus* and *R. parvulus* have similar dominant frequencies, about 2.15−2.89 kHz, calls of *R. gryllus* are distinguished from those of *R. parvulus*, from Thailand, by having a multi-note structure and a long duration 0.423−0.785 s, (versus calls with a single note; maintaining in a short duration 0.020−0.040 s; and the dominant frequency at 2.25−3.25 kHz in the description by Heyer, 1971).

Acoustic data from the advertisement calls of *R. gryllus* provide more traits for identifying this species from *Kurixalus bisacculus* that has many similar morphological characters as those of *Raorchestes gryllus*. The calls of *R. gryllus* differ from those of *Kurixalus bisacculus* by having the following properties: call duration 0.423−0.785 s, with multi-note; note unpulsed; the dominant frequency 2.15−2.89 kHz (versus the call duration 0.200 ± 0.02 s, with single note; note was composed of 27 ± 2.20 pulses; dominant frequency was 1.70 kHz in the description of Ziegler,

2002). Furthermore, in chorus, *Raorchestes gryllus* issues calls in call alternation pattern while *Kurixalus bisacculus* conducts calls in synchrony pattern (Ziegler, 2002).

This study also provides the first preliminary data on the calls of *Rhacophorus annamensis* and *R. calcaneus.* Calls generated by *R. annamensis* are complex with four types. The multi-type of call was also reported from other species of *Rhacophorus* such as *R. bimaculatus* (Heyer, 1971) and *R. kio* (Ziegler, 2002). Calls of *R. calcaneus* are also complicated with a compound of two types of notes like those of *R. annamensis*. Vocal properties of calls generated by *Rhacophorus* that are distributed in Vietnam can be compared in Table 23.

Table 23. Acoustic properties of calls of *Rhacophorus* known from Vietnam.
(All calls were recorded from Vietnam, except for *R. bimaculatus* from Thailand).

Species	Temperature & Humidity	Type	Call duration (s)	group	duration of group	Number of note(s) (notes/call)	Note duration (s)	Note repetition rate (notes/s)	Number of pulse (s) (pulses/note)	pulse repetition rate (pulses/s)	Call Dominant frequency (kHz)	References
R. annamensis	See Table 15	1	0.019–0.038	1	–	1	0.019–0.038	–	–	–	1.63–1.89	This study
		2	0.437–1.124	1	–	4–9	0.019–0.031	6.87–8.04	–	–	0.41–1.81	
		3	1.025–2.246	1	–	1–9	0.203–0.480	0.47–1.98	8.08–16.46	33.85–40.73	0.86–1.94	
		4	0.540–1.181	1	.042–0.211	1	0.042–0.211	–	2–9	23.81–42.94	1.27–2.06	
				2	.286–0.833	1–9	0.014–0.030	5.06–9.10	–	–		
R. bimaculatus	–	1	0.040–0.090	1	–	1	0.040–0.090	–	–	–	1.90–2.80	Heyer, 1971
		2	0.100–0.340	1	–	1–2	–	–	3–8	–	1.80–3.30	
R. calcaneus	See Table 19	1	4.515–6.209	1	.306–4.095	1	2.306–4.095	–	33–51	10.74–13.88	1.41–1.50	This study
				2	.451–2.160	1.5–4.5	0.020–0.166	0.86–1.64	3–5.5	26.28–29.49		
R. dennysi	26°C 71%	1	0.150–0.160	1	–	3	0.004–0.011	15–16	3–4	74–133	1.6	Ziegler, 2002
R. kio	26°C 71%	1	0.038–0.058 0.089–0.116 0.042–0.069	1	–	2	0.035–0.058 0.042–0.069	7–8	–	–	0.89	Ziegler, 2002
		2	0.237–0.267	1	–	–	–	0.023	10	–	1.00	
R. orlovi	–	1	0.010 ± 0.002	1	–	1	0.010 ± 0.002	1.36 ± 0.72	–	–	2.75 ± 0.29	Wildenhues et al., 2011

2.2. Multiple call types

Almost all of the recorded anurans have only one type of advertisement call with one or many notes. *Hylarana attigua* has two types of calls obviously different in call duration, number of pulses within the note, and dominant frequency (Table 10). Reasons for emitting different types of this species are unknown.

Rhacophorus annamensis also has multi-types of advertisement calls with four different types of calls. The most complicated call of this species is call type 4 that consisted of two types of notes. The question "when does this frog produce which type of call?" is also unknown and needs more studies in the future.

2.3. Chorus behavior

Many anurans species showed the behavior of forming chorus congregations; six of thirteen species (*Brachytarsophrys intermedia*, *Leptobrachium pullum*, *Leptolalax bidoupensis*, *Hylarana milleti*, *Raorchestes gryllus* and *Kurixalus baliogaster*) that have advertisement calls described here and two other microhylids gave evidence of calling in choruses. While *K. baliogaster* exhibited a pattern of call synchrony for dealing with the neighboring conspecific calling male, the others performed a call alternation pattern.

Although evidence of call alternation pattern of *Brachytarsophrys intermedia* and *Raorchestes gryllus* as well as the call synchrony of *Kurixalus baliogaster* in choruses were found, the ways of adjusting calls in choruses of these species are still unclear and need further study in the future.

In the call alternation model, frogs tended to make their calls different in order to avoid producing calls at the same time with calls of their neighbors. The calls could be issued with changes in the following acoustic properties: (1) call duration (*Leptobrachium pullum* & *Leptolalax bidoupensis*); (2) duration of intercall interval (*Leptolalax bidoupensis*); (3) number of pulses within a note (*Leptolalax bidoupensis* & *Hylarana milleti*); (4) pulse repetition rate (*Leptobrachium pullum*, *Leptolalax*

bidoupensis, & *Hylarana milleti*); (5) level intensity of the calls (*Leptobrachium pullum*, *Hylarana milleti*, maybe *Brachytarsophrys intermedia*); (6) dominant frequencies of the calls (*Leptobrachium pullum*); and (7) introduced new types of calls (*L. pullum*).

In multispecies aggregation, for minimizing surrounding audio signals from other species, the frogs could perform their calls in alternation pattern or a combination of alternation and synchrony patterns. They adjusted the call timing in the ways that their calls were separated with the ambient noises. This activity seems to be stricter for species that have the same dominant frequencies and microhabitat type than for species that have similar in only dominant frequencies or microhabitat type. Figure 37 shows calls emitted by *Hylarana milleti* and *Microhyla* sp. that had similar call dominant frequencies. Both species called from the same microhabitat. Their calls were produced without overlap of time. In another aggregation, each species *Leptobrachium pullum*, *Microhyla* sp., *Rhacophorus annamensis* & insect Orthoptera had similar in only dominant frequency or microhabitat with the others and performed calls with synchrony pattern (Figure 38).

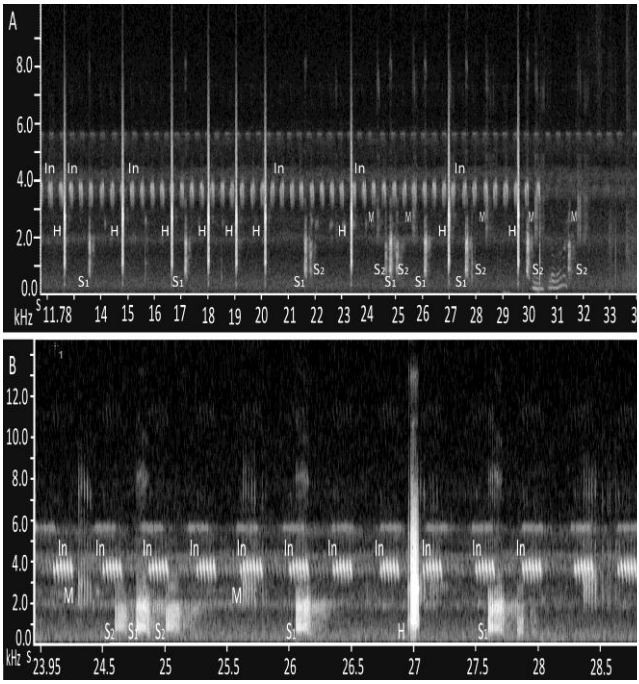

Figure 37. (A) Interspecific vocal interaction in a mixed chorus of multispecies community from the forest of BDNB NP; (B) magnitude part of (A).

The community included one male of *Hylarana milleti* (H) that emitted calls with dominant frequency of 2.72 kHz; one male of *Microhyla* sp. (M) that produced calls with dominant frequency of 2.77 kHz; two males of unknown species frog (S1 & S2) that emitting calls with dominant frequency of around 1.80 kHz; and an insect Orthoptera (In) that emitting calls with dominant frequency of 3.79 kHz. All the frogs and insect called concealed in grasses that grew on edge of a small pond, near to a road.

Hylarana milleti emitted calls alternating with the environmental noise from an insect Orthoptera. This frog adjusted its calls when new calls from two other frogs of unknown species and *Microhyla* happened. Calls of the unknown frog and *Microhyla* also were emitted with non time-overlap.

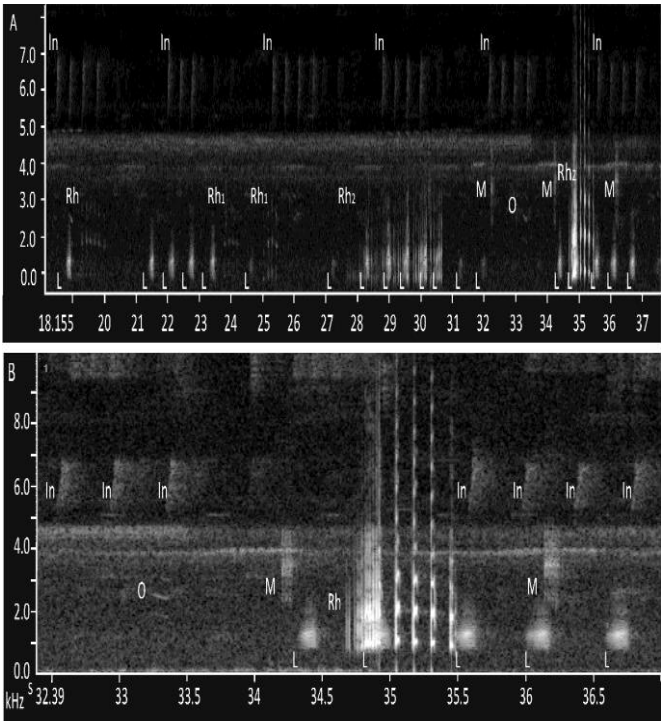

Figure 38. (A) Interspecific vocal interaction in a mixed chorus of multispecies community from the forest of CYS NP; (B) magnitude part of (A).

The community included one male of *Leptobrachium pullum* (L) that emitted calls with dominant frequency around 1.40 kHz; one male of *Microhyla* sp. (M) that produced calls with dominant frequency of 3.56 kHz; one male of *Occidozyga* sp. (O) call with dominant frequency around 2.45 kHz; and two males of *Rhacophorus annamensis* (Rh) that emitted calls with dominant frequency around 1.79 kHz; and an insect Orthoptera (In) that emitted calls with dominant frequency of 6.49 kHz. Males of *Leptobrachium pullum, Microhyla* sp. & *Occidozyga* called concealing in leaf litter near to a small pond. Males of *Rhacophorus annamensis* and insect called from branches of tree that hang over the pond, about 1.5–2.0 m, above the ground.

Calls of species were emitted at different time. Calls of *Leptobrachium pullum* were masked by those of *Rhacophorus annamensis* and partly by synchrony with a call of *Microhyla* sp.

3. Diversity and biogeography of the amphibian fauna of the Langbian Plateau

3.1. Diversity

A total of 44 species of anurans were recorded from the Langbian Plateau. The species richness of this plateau is likely still underestimated. The results indicated that the species richness in the forests of PB NP and TD NR are still well accumulated (Figure 7 B). Furthermore, many species registered for the Langbian Plateau from previous publications were not encountered during the surveys of this study such as *Odorrana banaorum*, *O. chloronota*, *O. morafkai*, and *Theloderma chuyangsinense* (Nguyen et al., 2009; BirdLife, 2010; Orlov et al., 2012). A number of 18 species found from CYS NP, in this study, is much lower than that recorded by Birdlife (2010) in the same forest (39 species, exclusive 14 unknown species). Reason for this difference is the difference in survey efforts conducted in between the two studies. Number of surveys in CYS NP achieved for this study was only two, with seven survey sites, at elevations between 900 m and 2000 m versus a number of 18 surveys, with a wider range of elevations, from 500 m to 2400 m, was obtained for the study in 2010 (Birdlife, 2010).

The results showed that the species compositions of amphibian assemblages in the Langbian Plateau have a pattern of species richness reaching peak in the middle of spatial gradient of elevation. Such species richness pattern responding to spatial elevation is also reflected by other organisms such as plants, insects, small mammals, birds, and other amphibians (Rahbek, 1995; Fu et al., 2006; Graham & Duda, 2011).

The altitudinal distribution pattern could be explained by the overlap of species compositions among anuran assemblages of the study area, at the elevations 600−1800 m (Figure 11).

Species richness also depends on survey efforts, elevations and forest types. Among the 38 survey sites, only three sites are belong to the cloud forests, at elevations ca. 2000 m and two sites are the cultivated areas, at elevations below 900 m.

Another reason is that most of the areas in the Langbian Plateau are dominated at the elevations of 900−1800 m and mainly covered by the evergreen forests and the mixed forests composed of hardwoods with bamboo. This point is illustrated by the CCA tri-plot for the amphibian populations of the Langbian Plateau (Figure 39 A).

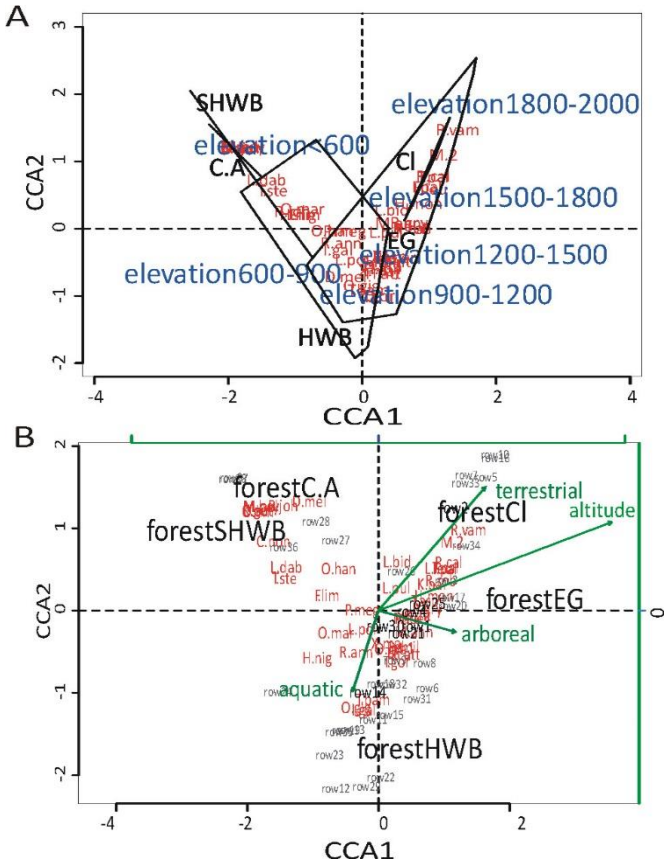

Figure 39. CCA ordination graph (scaling 2) for the amphibian assemblages in the Langbian Plateau. (A) The assemblages with ranges of elevations (blue) and forest types (black). (B) The assemblages with microhabitat utilization (green) and forest types.

Distributions of the amphibians in the Langbian Plateau among the forest types are associated with the pattern of altitudinal

distribution. Many species were found in the evergreen forests and the mixed forests composed of hardwoods and bamboo, at elevations between 900 and 1800 m. Only few species appeared in the cloud forests, at elevations above 1800 m.

Furthermore, the microhabitats are more diverse in the evergreen forests and in the mixed forests composed of hardwoods and bamboo than in other forest types (Figure 39 B). The evergreen forests harbor more terrestrial and arboreal microhabitats but less aquatic microhabitats than the mixed forests composed of hardwoods and bamboo. The microhabitat type of large streams with fast moving flows is rarer in the evergreen forests at higher elevations. This microhabitat houses some large-size species such as *Odorrana graminea*, *Hylarana milleti*, and *Xenophrys major*.

3.2. Biogeographic relationships of the amphibian communities among the forests within and adjacent the Langbian Plateau

There was a close relationship between the amphibian faunas of the SLSM and that of the eatern hills of Cambodia. This could be explained by the low ranges of elevations and forest types of the two areas. The eastern hills of Cambodia, at elevations from 109 m to 1500 m, is covered by evergreen, deciduous, and bamboo forests (Stuart et al., 2006). The survey sites in SLSM, at elevations up to 600 m, are coverd by the mixed forest composed of small hardwoods and bamboo. Therefore, the amphibian communities in these areas share many lowland species such as microhylids, *Rhacophorus annamensis*, *Hylarana nigrovittata*, *H. attigua*, and *Limnonectes dabanus.*

The results show that amphibian community of the Kon Tum Plateau is more similar to that of CYS NP than to those of other forests within the Langbian Plateau (Figure 40 A). This similarity can be figured out because CYS NP is the northernmost area of the Langbian Plateau, next to the Kon Tum Plateau and shares the same range of elevations and climate pattern with the Kon Tum Plateau.

The cluster analyses also agree with Bain and Hurley's results (2011) that the amphibian community of the Cardamom Mountains has a close relationship with that of the subregions Central Annamites and Southern Annamites (Figure 40 A& B).

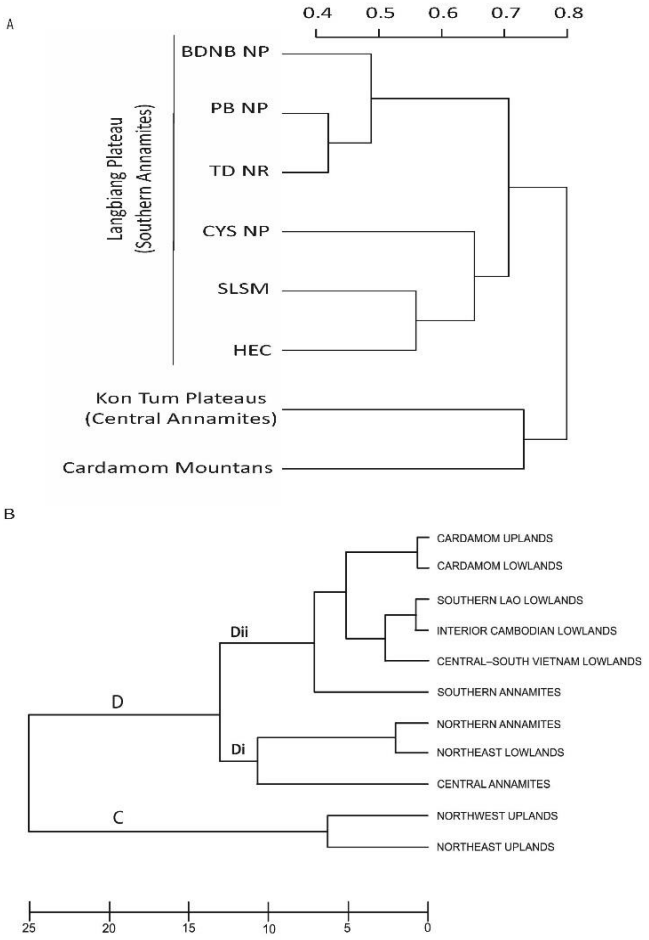

Figure 40. (A) Hierarchical cluster analyses using matrix of Jaccard distance among of the amphibian communities in the forests within the Langbian Plateau and two neighboring highlands (Kon Tum Plateau, Vietnam & Cardamom Mountains, Cambodia). (B) Cluster analysis phenogram for the amphibians of Indochina (Bain & Hurley, 2011).

4. Conservation potential

The Langbian Plateau owns a high diversity of endemic species. Among 44 recorded species, 14 species were considered as restricted to Indochina, three species restricted to the Southern Annamites subregion (Bain & Hurley, 2011), and six species (*Leptobrachium leucops*, *Leptolalax bidoupensis*, *Rhacophorus vampyrus*, *Theloderma palliatum*, *Microhyla* sp. 1, & *M.* sp. 2) are currently known only from the Langbian Plateau (see Table 24 for details).

Three of 44 recorded species were considered as nearly threatened and six other species as vulnerable status (IUCN, 2012 Rowley et al., 2011a). Six of these species are endemic species of Indochina region and restricted to evergreen forest or mixed forest composed of hardwoods with bamboo. Three species *Feihyla palpebralis*, *Kurixalus baliogaster*, and *Theloderma palliatum* were found only in small patches of the evergreen forests, at elevations above 1500 m in the Langbian Plateau. Occurrences of *Rhacophorus annamensis* were more common than other threatened species in the Langbian Plateau, at elevations up to 1300 m (Figure 41).

Among the 22 endemic and recently described anurans from the Langbian Plateau, most of them have distributions at elevations of 1500 m. Two species (*Limnonestes dabanus* and *Odorrana gigatympana*) occurred at elevations below 1000 m, and six species (*Leptobrachium leucops*, *Leptolalax bidoupensis*, *Microhyla* sp. 2, *Rhacophorus calcaneus*, *Rhacophorus vampyrus*, and *Theloderma palliatum*) could be found at elevations up to 2000 m. This indicates that the amphibian fauna of the cloud forest, at elevations ca. 2000 m, is not diverse but has a high level of endemicity.

Table 24. Status of threatened, endemic, and newly described species from the Langbian Plateau.
(*: species currently known only from the Langbian Plateau; SAN: endemic species of the Southern Annamites; I: endemic species of the Indochina; NT: Nearly Threatened; and VU: Vulnerable).

	Species	Status	Reference(s)
1.	*Brachytarsophrys intermedia*	I[1], VU[2]	[1]: Bain & Hurley, 2011; [2]: IUCN, 2012
2.	*Leptobrachium leucops*	new species*	Stuart et al., 2011
3.	*Leptobrachium pullum*	I	Bain & Hurley, 2011
4.	*Leptolalax bidoupensis*	new species*	Rowley et al., 2011b
5.	*Ophryophryne hansi*	I	Bain & Hurley, 2011
6.	*Microhyla annamensis*	I	Bain & Hurley, 2011
7.	*Microhyla* sp. 1	unknown*	
8.	*Microhyla* sp. 2	unknown*	
9.	*Limnonectes dabanus*	I	Bain & Hurley, 2011
10.	*Limnonectes poilani*	I	Bain & Hurley, 2011
11.	*Hylarana attigua*	I[1], VU[2]	[1]: Bain & Hurley, 2011; [2]: IUCN, 2012
12.	*Hylarana montivaga*	I	Bain & Hurley, 2011
13.	*Odorrana gigatympana*	I	Bain & Hurley, 2011
14.	*Feihyla palpebralis*	NT	IUCN, 2012
15.	*Kurixalus baliogaster*	SAN[1], VU[2]	[1]: Bain & Hurley, 2011; [2]: IUCN, 2012
16.	*Raorchestes gryllus*	I	Bain & Hurley, 2011
17.	*Rhacophorus annamensis*	I[1], VU[2]	[1]: Bain & Hurley, 2011; [2]: IUCN, 2012
18.	*Rhacophorus calcaneus*	I[1], NT	[1]: Bain & Hurley, 2011; [2]: IUCN, 2012
19.	*Rhacophorus robertingeri*	I, new species	Orlov et al., 2012
20.	*Rhacophorus vampyrus*	new species*	Rowley et al., 2010b
21.	*Theloderma bambusicolum*	SAN, new species	Orlov et al., 2012
22.	*Theloderma palliatum*	VU, new species*	Rowley et al., 2011a
23.	*Theloderma stellatum*	NT	IUCN, 2012
24.	*Theloderma truongsonense*	I	Bain & Hurley, 2011

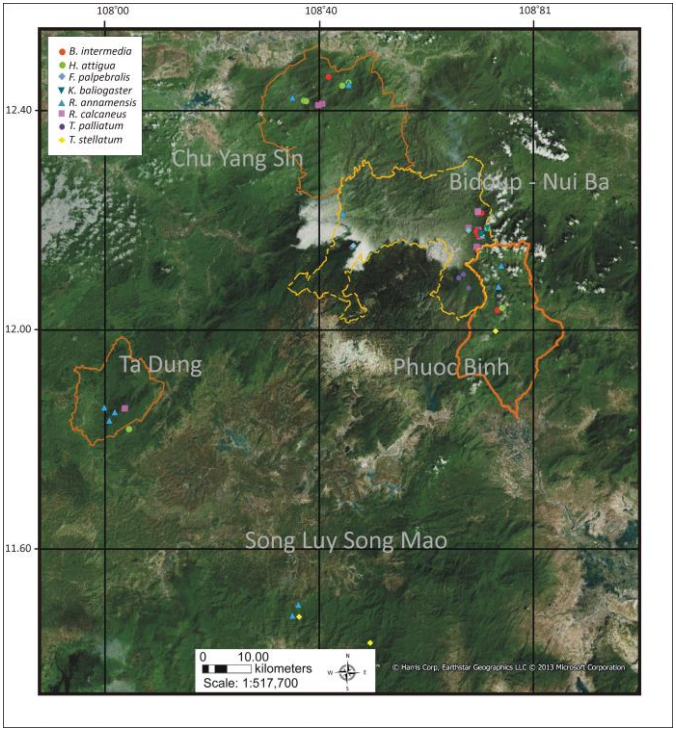

Figure 41. Map of threatened species recorded from the Langbian Plateau.

Previous reports showed that the wildlife of Vietnam has to deal with threats of overexploitation and habitat loss and fragmentation (Sterling et al., 2007, Birdlife, 2010). In the Langbian Plateau, the threat of overharvesting seems only to be true for mammals, birds, and reptiles but not for amphibians although they could be used for food by local people. There was none amphibian in the list of trading species recorded from the Chu Yang Sin National Park (Le & Mahood, 2008).

The major threat to the amphibian fauna of the Langbian Plateau is habitat loss and fragmentation caused by forest fire, agriculture and infrastructure development. The effects of loss and fragment forest in the Bidoup - Nui Ba National Park by the new road,

connecting between Da Lat and Nha Trang cities have been known (Birdlife, 2010). Besides many new local roads established for improving transportation systems in the Langbian Plateau and neighboring regions, a new main road “QL28”, 194 km in length, running from Phan Thiet, Binh Thuan Province to Gia Nghia, Dak Nong Province is developing. This road runs through the Ta Dung Natural Reserve. Another new main road “QL26”, 165 km in length, running between Ninh Thuan and Dak Lak provinces is also planned for constructing. These works could cause the strong fragmentation of forests within the areas.

The following effects on the amphibian community here are the noise caused by the traffic and the continuing loss of habitat caused by developing of fish farms. There are two small fish farms that have been developed since 2008 and 2009. The noticed point here, many rare and new species recorded from the Bidoup - Nui Ba National Park were found very near to one of these farms (the survey site 3). The impacts of these farms and human activity noises on amphibian population in this region has been not evaluated yet but there was evidence of this kind of effects on calling communication of *Hyla arborea*, in the estate of the Pierre Verots Foundations, France (Lenggagne, 2008). Other potential impacts caused by activities of the fish farms may be considered are the pollutions of water and changing in water system. These changes might strongly affect on the existences of both tadpoles and adults of the amphibians in this area.

CHAPTER V. CONCLUSIONS AND OUTLOOK

Conclusions

This study was carried out in order to gain an understanding of the amphibian communities of the Langbian Plateau, and achieved the following:

(1) Accounts and updates distributions for 44 amphibian species in the Langbian Plateau. This study also provides reproductive data of 11 anuran species with their microhabitat utilizations in the study area. Three new species have been recently described from the study area by our working groups (*Leptobrachium leucops*, *Leptolalax bidoupensis*, and *Rhacophorus vampyrus*). The species richness of the area is still underestimated, as the species accumulation curves of amphibian assemblages in the forests of Ta Dung Natural Reserve and Phuoc Binh National Park did not reach the plateau. During this work, the spatial structure of the amphibian communities in the Langbian Plateau with respect to elevations and forest types was determined. Most amphibian species occur at mid-elevations, at around 1500 m, in the evergreen forests and the mixed forests composed of hardwoods and bamboo. The amphibian species richness in the cultivated areas, at the elevations up to 900 m, was lower than those in the evergreen forests and in the mixed forests composed of hardwoods and bamboo. The amphibian community in the cloud forests, at the elevations around 2000 m, was the least but it contained most of the endemic species.

(2) A preliminary database of anuran advertisement calls of the Langbian Plateau was compiled, containing 13 anuran species. This database includes for the first time the calls of five of Indochina endemic species (*Hylarana attigua*, *Kurixalus baliogaster*, *Raorchestes gryllus*, *Rhacophorus annamensis*, and *R. calcaneus*). It is also the first time that

the advertisement call of *Hylarana milleti* has been described. Knowing anuran advertisement calls allows the more rapid identification of species in the field especially for species that have very similar morphology characters (e.g. distinguishing between *Hylarana attigua* and *H. milleti*). The database also provided interpretations of the intraspecific and interspecific acoustic interactions in choruses of three anurans (*Leptobrachium pullum*, *Leptolalax bidoupensis*, and *Hylarana milleti*) and evidence of the vocal behaviors of three other species (*Brachytarsophrys intermedia*, *Kurixalus baliogaster*, and *Raorchestes gryllus*).

(3) With respect to the biogeographic relationships between the amphibian fauna of the Langbian Plateau and those of neighboring areas, the cluster analyses indicated that the fauna of the eastern hills of Cambodia shows more intensive overlapping with that of the Song Luy and Song Mao watershed forests than with those of other communities within the Langbian Plateau. High similarities in species composition between the amphibian assemblages of the forests of the Chu Yang Sin National Park and that of the Kon Tum Plateau as well as between the amphibian assemblages of the forests of hills eastern of Cambodia and that of the Cardamom Mountains, southwestern Cambodia were also proven.

(4) The current major threat to the amphibian communities in the Langbian Plateau is the loss and fragmentation of habitats caused by agriculture and infrastructure developments. Many new local and main roads that run through and around the protected forests within the Langbian Plateau are being constructed. These effects may lead to other potential impacts of noise and water pollutions on the amphibian communities in the study area.

Outlook

As pointed out in the discussion, the amphibian species richness of the Langbian Plateau is currently underestimated. The surveys conducted in this study indicate that the species in the forests of Ta Dung Natural Reserve and Phuoc Binh National Park are still not fully known. Hence, further research in this field is recommended.

There were differences in acoustic properties of calls emitted by *Hylarana nigrovittata* among populations in central Vietnam (Quang Binh Province), southern Vietnam (Langbian Plateau), and Thailand. Combination of these findings and evidence from previous studies (Matsui et al., 2001, Ohler et al., 2002, Gawor et al., 2009; Frost, 2013) suggests that further studies should be done to confirm the taxonomic status of this species complex.

The multiple types of advertisement calls of *Hylarana attigua* and *Rhacophorus annamensis* were introduced. However, the question "when does the frog produce which type of call?" remains unanswered. Further studies with more focus on calling behavior in anurans in the study area are therefore suggested.

The evaluation of threats to amphibian communities of the Langbian Plateau highlighted the loss of habitats caused by agriculture and infrastructure development and the following potential impacts of noise and water pollutions. Therefore, more conservation work for restoring forests or linking isolated forests within the area is recommended. It will be also immergently necessary to assess the effects of traffic and aquaculture activities on the amphibian populations in this area.

SUMMARY

The Langbian Plateau is known as the southernmost extension of the Truong Son Range (or Annamite Mountains) in southern Vietnam. This area is the type locality of many amphibian species: six species described by Smith (1924) and another species, *Microhyla fusca*, discovered by Anderson (1942). In terms of species richness, Bourret (1942) recorded 19 species of amphibians from this plateau and the species number was increased to 67 in the most recent checklist of Nguyen et al. (2009). However, the knowledge about the amphibian fauna of the Langbian Plateau is still imperfect, in particular the species complexes and their natural history.

In this study, I focus on the taxonomy and ecology of the amphibian community of the Langbian Plateau by using morphological and bioacoustic approaches. Specific objectives of this study are: (1) to assess the species richness of the amphibian fauna, (2) to investigate the community structure of amphibians, (3) to evaluate biogeographic relationships of the amphibian faunas between the Langbian Plateau and adjacent areas, (4) to analyze advertisement calls of anurans, and (5) to determine the major threats to the amphibian fauna of the Langbian Plateau.

A total of 15 field surveys were conducted in Bidoup - Nui Ba National Park, Chu Yang Sin National Park, Phuoc Binh National Park, Ta Dung Natural Reserve, and Song Luy - Song Mao watershed forests during three years 2010−2012. The surveys were conducted in different forest types, including cloud forest, evergreen forest, mixed forest composed of hardwoods and bamboo, mixed forest composed of small hardwoods and bamboo, and cultivated area in buffer zone, at elevation range from 200 m to ca. 2000 m.

Resulting from this study, a collection of 651 specimens was used for morphological examination and 59 call records were made for bioacoustic analyzing. A total of 44 amphibians, belonging to 23 genera, six families were recorded from the Langbian Plateau. We also provided a number of new provincial records of amphibians

in southern Vietnam, comprising four species from Dak Lak Province, 21 species from Dak Nong Province, seven species from Lam Dong Province, 13 species from Ninh Thuan Province, and 14 species from Binh Thuan Province. Remarkably, three new species were recently discovered from the Langbian Plateau by our group working, namely *Leptobrachium pullum*, *Leptolalax bidoupensis*, and *Rhacophorus vampyrus*.

In the first part of the results of this dissertation, a list and species descriptions of all recorded species were presented in detail. Moreover, additional information about reproductive biology of 15 species, comprising of three species of Megophryidae, one species of Microhylidae, two species of Ranidae and five species of Rhacophoridae, was also provided.

The distribution pattern of amphibian species from the Langbian Plateau was presented in the second part. In terms of geographic distribution, 30 amphibian species were recorded from Bidoup - Nui Ba National Park, 18 from Chu Yang Sin National Park, 20 from Phuoc Binh National Park, 25 from Ta Dung Natural Reserve, and 18 from Song Luy Song Mao watershed forest. Among 44 recorded anurans, nine species were found in cloud forests, 32 species in evergreen forests, 21 species in mixed forests composed of hardwoods and bamboo, 18 species in mixed forests composed of small hardwoods and bamboo, and 11 species in cultivated areas. Although the anuran fauna of the cloud forests is not diverse, it contains most of the endemic species. Six of nine species found in the cloud forests are restricted to Indochina. The species composition of the cloud forests is more similar to that of the evergreen forests than to those of other forest types. The anuran fauna of the evegreen forests is more similar to that of the mixed forests composed of hardwoods and bamboo than to that of the cultivated areas.

In terms of altitudinal distribution, the highest species richness is known at elevations around 1500 m. The diversity decreases at elevations below 900 m and above 1800 m. The CCA biplot for the communities at different elevations showed the overlap in species composition among the ranges of elevations from 600 to

1800 m with the 95% confidence ellipses, estimated for each range of elevations. With respect to the life-mode segregation, the more distance is away from the water bodies, the less number of amphibian species is found. In Langbian Plateau, we recorded 27 aquatic species, 28 terrestrial species and 28 arboreal species. The species number of amphibians decreases at higher elevations because the forests on mountain tops harbor more terrestrial and arboreal species but fewer aquatic species than the forests at lower elevations.

The third part of the results mentioned about the biogeographic relationships. The cluster analyses indicated that the amphibian fauna of the eastern hill of Cambodia, a western extended part of the Langbian Plateau, intensively overlapped with that of the Song Luy Song Mao watershed forest. The amphibian fauna of the Langbian Plateau is more similar to that of the Kon tum Plateau than to that of the Cardamom Mountains.

In the fourth part of the results, advertisement calls of 13 anuran species from the Langbian Plateau were described (Megophryidae: 5, Ranidae: 3, and Rhacophoridae: 5). The call descriptions of five Indochina endemic species, listed in the IUCN Red List as vulnerable or nearly threatened (*Brachytarsophrys intermedia* - VU, *Hylarana attigua* - VU, *Kurixalus baliogaster* - VU, *Rhacophorus annamensis* - VU, and *R. calcaneus* - NT), were introduced for the first time. It is also the first time that the advertisement call of *Hylarana milleti* has been described.

Many anurans showed the behavior of forming chorus congregations, six of 13 species that have advertisement calls described here gave proofs of calling in choruses. Intraspecific chorus behaviors of three species were interpreted (*Leptobrachium pullum*, *Leptolalax bidoupensis*, and *Hylarana milleti*). Proofs of interspecific chorus behaviors of anurans in the Langbian Plateau were also provided.

In the discussion part, taxonomic problems of the morphologically similar species or species complexes are mentioned. Based on specimen examination several taxa are likely species complexes (e.g., *Hylarana nigrovittata*, *Polypedates*

leucomystax, *Brachytarsophrys intermedia*, *Raorchestes gryllus*, *Rhacophorus calcaneus* and *R. robertingeri*).

Another aim of this study is linking the morphology and bioacoustics to support for taxonomic identification. Therefore, I compared the advertisement call of morphologically similar species of the families Megophryidae, Ranidae and Rhacophoridae (e.g., among the populations of *Hylarana nigrovittata* complex or between *H. attigua* and *H. milleti*).

Regarding the biogeographic relationships, our cluster analyses supported the results of Bain and Hurley (2011) that the amphibian fauna of the Cardamom Mountains is closely related to that of the Kon Tum Plateau.

Finally, conservation potential and threats to the amphibians of the Langbian Plateau were also evaluated. On the one hand, the amphibian fauna of the Langbian Plateau has a high conservation potential because of a high level of species diversity with 44 recorded species and a large number of endemic/threatened species. A total of 14 species are endemic to Indochina, two species are restricted to the subregion Southern Annamites, and six species are currently known only from the Langbian Plateau. Nine species are listed in the IUCN Red List (2012) as globally threatened species (six species as vulnerable and three species as nearly threatened). On the other hand, the amphibian species in the Langbian Plateau are facing a decline because of habitat loss and fragmentation.

Based on these results, further research that focuses on the following fields is recommended: (1) taxonomic and distributional status of the amphibians in the Langbian Plateau; (2) calling behavior in anurans in the Langbian Plateau and adjacent areas; and (3) more conservation work for restoring forests or linking isolated forests, and pollution controll management in the Langbian Plateau.

ZUSAMMENFASSUNG

Das Langbian-Plateau ist der südlichste Ausläufer des Truong Son-Gebietes (= Annamitisches Bergland) im südlichen Vietnam. Das Gebiet ist die Typuslokalität vieler Amphibienarten: sechs von Smith (1924) beschriebenen und einer weiteren, von Anderson (1942) entdeckten, *Microhyla fusca*. In Bezug auf Artenreichtum meldete Bourret (1942) 19 Amphibienarten von diesem Plateau, und durch die rezente Checklist von Nguyen et al. (2009) erhöhte sich die Artenzahl auf 67. Allerdings ist das Wissen über die Amphibienfauna des Langbian-Plateaus immer noch lückenhaft, speziell was die Artenkomplexe, aber auch die Naturgeschichte der Arten betrifft.

In dieser Studie konzentriere ich mich auf die Taxonomie und Ökologie der Amphibienzönose des Langbian-Plateaus durch Verwendung morphologischer und bioakustischer Ansätze. Spezielle Ziele der Studie sind: 1. den Artenreichtum der Amphibienfauna zu ermitteln, 2. die Zönosenstruktur der Amphibien zu untersuchen, 3. die zoogeographischen Beziehungen der Amphibienfaunen zwischen dem Langbian-Plateau und den angrenzenden Gebieten zu ermitteln, 4. die Paarungsrufe der Anuren zu analysieren, und 5. die Hauptbedrohungsfaktoren für die Amphibienfauna des Langbian-Plateaus zu ermitteln.

Insgesamt wurden zwischen den Jahren 2010 und 2012 insgesamt 15 Feldexkursionen durchgeführt, die in den Bi Doup - Nui Ba-Nationalpark, den Chu Yang Sin-Nationalpark, das Ta Dung-Naturreservat und die Song Luy - Song Mao-Wasserscheiden-Wälder führten. Die Untersuchungen fanden in verschiedenen Waldtypen statt, z.B. Nebelwald, immergrüner Wald, Mischwald aus Hartholz und Bambus, Mischwald aus kleinen Harthölzern und Bambus, und Kulturland in den Pufferzonen: der untersuchte Höhengradient reichte von 200 bis ca. 2000 m NN.

Im Ergebnis der Erfassungen wurde eine Sammlung von insgesamt 651 Exemplaren zusammengebracht, die für morphologische Untersuchungen dienten, und 59 Rufaufnahmen für die bioakustischen Analysen wurden gemacht. Eine Gesamtzahl von 44

Amphibienarten, verteilt auf 23 Gattungen, und sechs Familien konnte vom Langbian-Plateau nachgewiesen werden. Es ergaben sich dabei auch mehrere Provinz-Neunachweise für das südliche Vietnam, so 4 Arten für die Provinz Dak Lak, 21 für die Provinz Dak Nong, 7 für die Provinz Lam Dong, 13 für die Provinz Ninh Thuan, und 14 Arten schließlich für die Provinz Binh Thuan. Bemerkenswert ist die Entdeckung von drei neuen Arten aus dem Langbian-Plateau durch unser Team, nämlich *Leptobrachium pullum, Leptolalax bidoupensis* und *Rhacophorus vampyrus*.

Im ersten Teil der vorliegenden Dissertation gebe ich eine kommentierte Artenliste und detaillierte Beschreibung aller im Untersuchungsgebiet vorgefundenen Arten. Darüber hinaus können zu 11 Arten neue Daten zur Reproduktionsbiologie gegeben werden, und zwar von drei Megophryiden, einem Microhyliden, zwei Raniden und fünf Rhacophoriden.

Im zweiten Teil werden die Verbreitungsmuster der Amphibienarten des Langbian-Plateaus dargestellt. Bezüglich ihrer geographischen Verbreitung werden 30 Arten aus dem Bidoup - Nui Bah-Nationalpark, 18 aus dem Chu Yang Sin-Nationalpark, 20 aus dem Phuoc Binh-Nationalpark, 25 aus dem Ta Dung Naturreservat und 18 aus den Song Luy Song-Wasserscheiden-Wäldern nachgewiesen. Unter den 44 Anurenarten wurden 9 in Nebelwäldern, 32 in immergrünen Wäldern, 21 in Mischwäldern aus Hartholz und Bambus, 18 in Mischwäldern aus kleinen Harthölzern und Bambus, und 11 im Kulturland nachgewiesen. Obwohl die Diversität in den Nebelwäldern eher niedrig ist, gibt es dort die meisten Endemiten. Sechs der neun im Nebelwaldbereich nachgewiesenen Arten gibt es nur in Indochina. Die Artenzusammensetzung in den Nebelwäldern ist der der immergrünen Wälder ähnlicher als jedem anderen Waldtyp. Die der immergrünen Wälder ähnelt mehr den Artengemeinschaften der Mischwälder aus Hartholz und Bambus als denen des Kulturlandes und der Mischwälder aus kleinen Harthölzern und Bambus.

Bezüglich der Höhenverbreitung finden sich die höchsten Artenzahlen in Höhenlagen um 1500 m. Die Diversität nimmt

dementsprechend unter 900 m sowie über 1800 m NN ab. Der CCA Biplot für die Zönosen auf verschiedenen Höhenstufen zeigte Überlappungen in den Artenzusammensetzungen zwischen den Höhenstufen von 900-1800 m mit 95% Konfidenz-Ellipsen. Bezogen auf Trennung nach Lebensweisen gilt: Je größer der Abstand zu Wasserkörpern, desto geringer die Zahl der Amphibienarten. Sie nimmt deshalb in größeren Höhenlagen ab, weil die Wälder auf den Berggipfeln mehr terrestrische und arboreale, aber weniger aquatische Arten, wie es in niedrigeren Lagen der Fall ist, beherbergen.

Der dritte Teil der Ergebnisse behandelt die biogeographischen Beziehungen.

Im vierte Teil der Dissertation werden die Paarungsrufe von 13 Anurenarten des Langbian-Plateaus beschrieben: 5 Megophryiden, 3 Raniden, und 5 Rhacophoriden. Darunter sind fünf in Indochina endemische Arten, die in der Roten Liste der IUCN als "Vulnerable" oder "Near Threatened" geführt werden: *Brachytarsophrys intermedia* - VU, *Hylarana attigua* - VU, *Kurixalus baliogaster* - VU, *Rhacophorus annamensis* - VU, und *R. calcaneus* - NT, deren Rufe erstmalig beschrieben werden. Ebenfalls zum ersten Mal wird der Paarungsruf von *Hylarana milleti* beschrieben.

Viele Anuren zeigten das Verhalten, sich zu Rufchören zu versammeln, bei sechs von 13 Arten, deren Rufe hier beschrieben werden, war dies der Fall. Bei intraspezifischen Chören konnte das an drei Beispielen (*Leptobrachium pullum*, *Leptolalax bidoupensis* und *Hylarana milleti*) konnte dies im Detail gezeigt werden. Auch interspezifische Chöre konnten bei den Fröschen des Langbian-Plateaus nachgewiesen und analysiert werden.

Im Diskussionsteil werden taxonomische Probleme, die sich bei morphologisch ähnlichen Arten und bei Artenkomplexen ergeben, erörtert. Aufgrund der untersuchten Belegexemplare erweisen sich folgende Arten als vermutliche Artenkomplexe: *Hylarana nigrovittata, Polypedates leucomystax, Brachytarsophryas intermedia, Raorchestes gryllus, Rhacophorus calcaneus* und *R. robertingeri*).

Ein weiteres Ziel der vorliegenden Arbeit war es, Morphologie und Bioakustik für taxonomische Schlussfolgerungen miteinander zu verbinden. Daher wurden speziell die Paarungsrufe einander ähnlicher Arten der Familien Megophryidae, Ranidae und Rhacophoridae verglichen (z.B. die Populationen des *Hylarana nigrovittata*-Komplexes und die von *H. attigua* gegenüber *H. milleti*).

Bezüglich der biogeographischen Beziehungen zeigen meine Clusteranalysen, dass die Amphibienzönose der Berge Ost-Kambodschas, westliche Ausläufer des Langbian-Plateaus, eine große Überlappung mit der des Song Luy Song-Wasserscheidenwaldes aufweist. Insgesamt ähnelt die Amphibienfauna des Langbian-Plateaus mehr der des Kon Tum-Plateaus als der der Cardamom-Berge in SW-Kambodschas. Die Clusteranalysen bestätigen die Ansicht von Bain & Hurley (2011), dass die Froschfauna letzterer eng mit der des Kon Tum-Plateaus verwandt ist.

Schließlich wurden auch das Naturschutz-Potenzial und die Bedrohungen für die Amphibien des Langbian-Plateaus evaluiert. Es gibt hier ein hohes Naturschutzpotenzial, das sich aus der reichen Diversität mit 44 sympatrischen Arten und einer beachtlichen Zahl endemischer und bedrohter Taxa ergibt: Insgesamt 14 Arten sind endemisch in Indochina, zwei sind auf die süd-annamitische Subregion beschränkt, und sechs sind derzeit nur vom Langbian-Plateau bekannt. Neun Arten stehen auf der Roten Liste der IUCN (2012) als global gefährdet, sechs als VU und drei als NT. Also sehen auch die Frösche des Langbian-Plateaus einem drastischen Rückgang durch Habitatfragmentierung und -verlust entgegen.

Insgesamt werden auf der Grundlage der hier vorgelegten Ergebnisse folgende Vorschläge gemacht: 1. weitere Amphibien-Surveys auf dem Langbian-Plateau; 2. weitere bioakustische Untersuchungen dort; und 3. mehr Naturschutzarbeit zur Restauration der Wälder und Wiederverlinkung von Waldfragmenten, sowie Kontrollmanagement gegen Umweltverschmutzung und -zerstörung.

ACKNOWLEDGEMENTS

I am very grateful to my first supervisor, Prof. Dr. Wolfgang Böhme, who has supervised and always encouraged me throughout my study.

I would like to thank my second supervisor, Prof. Dr. J. Wolfgang Wägele for providing me many supports during the time of my study.

I very appreciate Assoc. Prof. Dr. Thomas Ziegler (Cologne Zoo), Dr. Nguyen Quang Truong, and Dr. Jodi Rowley (Australian Museum) who have provided me with very valuable professional experience, encouragements during this study, and very helpful comments for this dissertation.

I would like to thank Dr. Dennis Rödder who introduced me to the field of bioacoustics.

I would like to thank Ms. Ursula Bott for all her kind help during the time of my study at The Zoological Research Museum Alexander Koenig, Bonn, Germany (ZFMK).

The Ministry of Environment of Forests gave me a permit to survey in protected forests in Vietnam. I acknowledge the managers and staffs of the Bidoup - Nui Ba National Park, the Chu Yang Sin National Park, the Phuoc Binh National Park, the Ta Dung Nature Reserve, and the Song Luy and Song Mao watershed forests for their supports and arrangements. Without these great helps my surveys were not successful.

I would like to thank Dr. David Kizirian (American Museum of Natural History) for very kind supports for the surveys in Song Luy Song Mao watershed forest, and the loan of specimens.

Many thanks to students from The Faculty of Biology, University of Science, Ho Chi Minh City, Vietnam who gave me great assistants in the fieldwork.

My study in Germany was supported by the scholarships from The Vietnamese Ministry of Education and Training (322 Project) and The German Academic Exchange Service (DAAD); The Zoological Research Museum Alexander Koenig, Bonn, Germany

(ZFMK); and The University of Science, Ho Chi Minh City, Vietnam (US).

My surveys were conducted with the financial supports from The Alexander Koenig Society (Alexander Koenig Gesellschaft - AKG), The Alexander Koenig Foundations (Alexander Koenig Stiftung - AKS), IDEA WILD, and Nagao Natural Environment Foundation (NEF).

And, I would like to thank all my colleagues, friends, and my family who shared many things of life and study during the time of my study.

REFERENCES

Andersson L. G. 1942. A small collection of frogs from Annam collected in the years 1938–39 by Bertil Björkegren. Arkiv för Zoologi. Stockholm. 34 (6): 1–11.

Averyanov L. V., L. k. Phan, H. T. Nguyen and D. K. Harder. 2003. Phytogeographic review of Vietnam and adjacent areas of Eastern Indochina. Komarovia. 3: 1–83.

Bain R. H., A. Lathrop, R. W. Murphy, N. L. Orlov and C. T. Ho. 2003. Cryptic species of a cascade frog from southeast Asia: taxonomicrevisions and descriptions of six new species. American Museum Novitates. 3417: 1–60.

Bain R. H., B. L. Stuart and N. L. Orlov. 2006. Three new Indochinese species of Cascade frogs (Amphibia: Ranidae) allied to *Rana archotaphus*. Copeia. 1: 43–59.

Bain R. H. and M. M. Hurley. 2011. A biogeographic synthesis of the amphibians and reptiles of Indochina. Bulletin of The American Museum of Natural History. 360: 1–138.

Bee M. A., R. Suyesh and S. D. Biju. 2013. Vocal behavior of the Ponmudi Bush Frog (*Raorchestes graminirupes*): Repertoire and individual variation. Herpetologica. 69 (1): 22–35.

Berry P. Y. 1975. The amphibian fauna of Peninsular Malaysia. Tropical Press, Kuala Lumpur. 129 pp.

Biju S. D., YogeshShouche, A. Dubois, S. K. Dutta and F. Bossuyt. 2010. A ground-dwelling rhacophorid frog from the highest mountain peak of the Western Ghats of India. Current Science. 98: 1119–1125.

Birdlife International. 2001a. Sourcebook of existing and proposed protected areas in VietnamBirdlife International and the Forestry Inventory and Planning Institute, Hanoi, Vietnam.

BirdLife International. 2001b. The directory of important bird areas in Vietnam. Birdlife International and the Forestry Inventory and Planning Institute, Hanoi, Vietnam.

BirdLife International. 2010. The biodiversity of Chu Yang Sin National Park, Dak Lak Province, Vietnam. Compiled and edited by Hughes, R. BirdLife International. BirdLife International in Indochina. Ha Noi, Vietnam.

Boulenger G. A. 1920. A monograph of the South Asian, Papuan, Melanesian and Australian frogs of the genus *Rana*. Records of the Indian Museum. 20: 1–226.

Bourret R. 1942. Les Batrachiens De L'Indochine. Gouvernement General de L'Indochine. 547 pp.

Briggs V. S. 2010. Call trait variation in morelet's tree frog, *Agalychnis moreletii*, of Belize. Herpetologica. 66 (3): 241–249.

Brown R. M. and B. L. Stuart. 2012. Pattern of biodiversity of discovery through time: an historical analysis of amphibian species discoveries in the Southeast Asia mainland and adjacent island archipelagos. Biotic evolution and environmental change in Southeast Asia. D. Gower, K. Johnson, J. Richardsonet al. Cambridge University Press**:** 348–389.

Canavero A., M. Arim, D. e. Naya, A. Camargo, I. d. Rosa and R. Maneyro. 2008. Calling activity patterns in an anuran assemblage: the role of seasonal trends and weather determinants. North-Western Journal of Zoology 4(1): 29–41.

Cocroft R. B. and M. J. Ryan. 1995. Patterns of advertisement call evolution in toads and chorus frogs. Animal Behavior. 49: 283–303.

Crouch W. B. and P. W. C. Paton. 2002. Assessing the use of call surveys to monitor breeding anurans in Rhode Island. Journal of Herpetology. 36 (2): 185–192.

Dijk P. P. v. and R. Bain. 2004. *Theloderma gordoni*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. Downloaded on 22 March 2013.

Duellman W. E. and L. Trueb. 1994. Biology of amphibians. The Johns Hopkins University Press. 670 pp.

Frost D. R. 2013. Amphibian species of the World: an online reference. Version 5.6 (9 January 2013). Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/index.html. American Museum of Natural History, New York, USA.

Fu C., X. Hua, J. Li, Z. Chang, Z. Pu and J. Chen. 2006. Elevation patterns of frogs species richness and endmic richness in the Hengduan Mountains, China: geometric contraints, area and climate effects. Ecography. 29: 919–927.

Gawor A., R. Hendrix, M. Vences, W. Böhme and T. Ziegler. 2009. Larva mophology in four species of *Hylarana* from Vietnam and Thailand with comments on the taxonomy of *H. nigrovittata* sensu latu (Anura: Ranidae). Zootaxa. 2051: 1–25.

Gawor A., K. V. D. Straeten, D. Karbe, U. Manthey and T. Ziegler. 2011. Reproduction and development of the dark-sided frog *Hylarana nigrovittata* sensu lato at the Cologne Zoo. Salamandra. 47 (1): 1–8.

Gerhardt C. H. 1994. The evolution of vocalization in frogs and toads. Annual Review of Ecology and Systematics. 25: 293–324.

Gerhardt H. C. and F. Huber. 2002. Acoustic communication in insects and anurans: common problems and diverse solutions. University of Chicago Press. 531 pp.

Glaw F. and M. Vences. 1994. A field guide to the amphibians & reptiles of Madagascar. 480 pp.

Graham J. H. and J. J. Duda. 2011. The humpbacked species richness-curve: A continent rule for community ecology. International Journal of Ecology. Article ID 868426: 15 pp.

Grismer L. L., T. Neang, T. Chav, J. Perry L. Wood, J. R. Oaks, J. Holden, J. L. Grismer, T. R. Snutz and T. M. Youmans. 2008a. Additional amphibians and reptiles from the Phnom Samkos wildlife sanctuary in northwestern Cardamom mountains, Cambodia, with comments on their taxonomy and the discovery of three new species. The Raffles Bulletin of Zoology. 56 (1): 161-175.

Grismer L. L., N. Thy, C. Thou and J. L. Grismer. 2008b. Checklist of the amphibians and reptiles of the Cardamom region of southwestern Cambodia. Cambodian Journal of Natural History. 1: 12–28.

Guayasamin J. M., E. Lehr, D. Rodri´Guez and C. Aguilar. 2006. A new species of glass frog (Centrolenidae: *Cochranella ocellata* group) from central Peru. Herpetologica. 62 (2): 163–172.

Guaysamin J. M., M. B. Bustamante, D. Almeida-Reinoso and W. C. Funk. 2006. Glass frogs (Centrolenidae) of Yanayacu Biological Station, Ecuador, with the description of a new species and comments on centrolenid systematics. Zoological Journal of the Linnean Society. 147: 489–513.

Hauselberger K. F. and R. A. Alford. 2005. Effects of season and weather on calling in the Australian microhylid frogs *Austrochaperina robusta* and *Cophixalus ornatus*. Herpetofauna. 61 (4): 349–363.

Hendrix R., W. Böhme and T. Ziegler. 2009. The tadpole of the Helmeted Toad, *Ingerophrynus galeatus* (Günther, 1864), from Vietnam (Anura: Bufonidae). Herpetology Notes. 2: 155–160.

Heyer W. R. 1971. Mating calls of some frogs from Thailand. Fieldiana Zoology. 58 (6): 21.

Hoang D. M., B. V. Tran and L. Vu. 2010. Population status of the yellow-cheeked crested gibbon (*Nomascus gabriellae*) in Ta Dung Nature Reserve, Dak Nong Province, Vietnam. Fauna & Flora International / Conservation International, Hanoi, Vietnam

Inger R. F., N. Orlov and I. Darevsky. 1999. Frogs of Vietnam: A report on new collections. Fieldiana: Zoology. 92: 1–46.

IUCN. 2012. IUCN Red List of Threatened Species. Version 2012.2. <http://www.iucnredlist.org/>. Downloaded on 22 March 2013.

Kelley D. B. 2004. Vocal communication in frogs. Current Opinion in Neurobiology. 14 (6): 751–757.

Kindt R. and R. Coe. 2005. Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. Nairobi: World Agroforestry Centre (ICRAF).

Kuraishi N., M. Matsui, A. Hamidy, D. M. Belabut, N. Ahmad, S. Panha, A. Sudin, H. S. Yong, J.-P. Jiang, H. Ota, H. T. Thong and K. Nishikawa. 2013. Phylogenetic and taxonomic relationships of the *Polypedates leucomystax* complex (Amphibia). Zoologica Scripta. 42 (1): 54–70.

Kuramoto M. and S. H. Joshy. 2006. Morphological and acoustic comparisons of *Microhyla ornata, M. fissipes*, and *M. okinavensis* (Anura: Microhylidae). Current Herpetology. 25 (1): 15–27.

Ladefoged P. 1962. Elements of acoustic phonetics. Chicago and London. University of Chicago Press. Ltd., London. 216 pp.

Lathrop A., R. W. Murphy, N. L. Orlov and C. T. Ho. 1998. Two new species of *Leptobrachium* (Anura: Megophryidae) from the Central Highlands of Vietnam with a redescription of *Leptobrachium chapaense*. Russian Journal of Herpetology 5(1): 51–60.

Le T. T. and M. H. Tran. 2000. A rapid field survey of Kalon Song Mao Nature Reserve (Binh Thuan Province) and Lo Go - Sa Mat Nature Reserve (Tay Ninh Province), Vietnam. Hanoi: BirdLife International Vietnam Programme and the Forest Inventory and Planning Institute.

Le T. T. and S. Mahood. 2008. The illegal wildlife and timber trade network around Chu Yang Sin National Park, Dak Lak Province, Vietnam. BirdLife International Vietnam Programme, Hanoi, Vietnam.

Lenggagne T. 2008. Traffic noise affects communication behaviour in a breeding anuran, *Hyla arborea*. Biological Conservation. 141: 2023–2032.

Li J., D. Rao, R. W. Murphy and Y. Zhang. 2011. The systematic status of Rhacophorid frogs. Asian Herpetological Research 2(1): 1–11.

Liem S. S. 1970. The morphology, systematics, and evolution of the old World treefrogs (Rhacophoridae and Hyperoliidae). Fieldiana: Zoology. 57: 1–145.

Matsui M., K. Nishikawa, W. Khonsue, S. Panha and J. Nabhittabhata. 2001. Allozymic variation in *Rana nigrovittata* (Amphibia: Anura) within Thailand with special reference to the taxonomic status of *R. mortenseni*. The Natural History Journal of Chulalongkorn University. 1 (1): 15–22.

Narins P. M., A. S. Feng, R. R. Fay and A. N. Popper. 2007. Hearing and sound communication in amphibians. Springer Science + Business Media, LLC. 362 pp.

Nguyen H. D. and A. N. Kuznetsov. 2012. Biodiversity and geomorphology of Bidoup Nui Ba National Park. Science and Technology. 347 pp.

Nguyen S. V. and C. T. Ho. 1996. A checklist of reptiles and amphibians of Vietnam. Hanoi. Science and Technology.

Nguyen S. V., C. T. Ho and T. Q. Nguyen. 2005. A checklist of amphibians and reptiles of Vietnam. Agriculture Publishing House. 180 pp.

Nguyen S. V., C. T. Ho and T. Q. Nguyen. 2009. Herpetofauna of Vietnam. Frankfurt am Main. 768 pp.

Nguyen T. Q., M. D. Le, C. T. Pham, T. T. Nguyen, M. Bonkowski and T. Ziegler. 2013a. A new species of *Gracixalus* (Amphibia: Anura: Rhacophoridae) from northern Vietnam. Organisms Diversity & Evolution. 13: 203–214.

Nguyen T. Q., T. M. Phung, M. D. Le, T. Ziegler and W. Böhme. 2013b. First record of the genus *Oreolalax* (Anura: Megophryidae) from Vietnam with description of a new species. Copeia. 2: 213–222.

Nguyen V. K., H. T. Nguyen, L. k. Phan and H. T. Nguyen. 2000. Bioclamatic diagrams of Vietnam. Hanoi. Vietnam National University Publishing House. 125 pp.

Nishikawa K., M. Matsui and N. L. Orlov. 2012. A new striped *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from Kon Tum Plateau, Vietnam. Current Herpetology. 31 (1): 28–37.

Nishikawa K., M. Matsui and T. T. Nguyen. 2013. A new species of *Tylototriton* from northern Vietnam (Amphibia: Urodela: Salamandridae). Current Herpetology. 32 (1): 34–49.

Ohler A., S. R. Swan and J. C. Daltry. 2002. A recent survey of the amphibian fauna of the Cardamom mountains southwest Cambodia with description of three new species. The Raffles Bulletin of Zoology. 50 (2): 465–481.

Ohler A. 2003. Revision of the genus *Ophryophryne* Boulenger, 1903 (Megophryidae) with description of two new species. Alytes. 21 (1–2): 23–44.

Ohler A., A. Teynie and P. David. 2004. A green-eye *Leptobrachium* (Anura: Megophryidae) from southern Laos. The Raffles Bulletin of Zoology. 52 (2): 695–700.

Ohler A. and S. Grosjean. 2005. Color pattern and call variation in *Kalophrynus* from south-east Asia. Herpetozoa. 18 (3/4): 99–106.

Ohler A., K. C. Wollenberg, S. Grosjean, R. Hendrix, M. Vences, T. Ziegler and A. Dubois. 2011. Sorting out *Lalos*: description of new species and additional taxonomic data on megophryid frogs from northern Indochina (genus *Leptolalax*, Megophryidae, Anura). Zootaxa. 3147: 1–83.

Orlov N. L., A. Lathrop, R. W. Murphy and C. T. Ho. 2001. Frogs of the family Rhacophoridae (Anura: Amphibia) in the northern Hoang Lien Mountains (Mountant Fan Si Pan, Sa Pa District, Lao Cai Province), Vietnam. Russian Journal of Herpetology. 8 (1): 17–44.

Orlov N. L., R. W. Murphy, N. B. Anajeva, S. A. Ryabov and C. T. Ho. 2002. Herpetofauna of Vietnam, a checklist. Part I. Amphibia. Russian Journal of Herpetology. 9 (2): 81–104.

Orlov N. L. 2005. A new species of the genus *Vibrissaphora* Liu, 1945 (Anura: Megophryidae) from mount Ngoc Linh (Kon Tum Province) and analysis of the extent of species overlap in the fauna of amphibians and reptiles of the north-west of Vietnam and central highlands. Russian Journal of Herpetology. 12 (1): 17–38.

Orlov N. L. and C. T. Ho. 2005. A new species of *Philautus* from Vietnam (Anura: Rhacophoridae). Russian Journal of Herpetology. 12 (2): 135–142.

Orlov N. L., N. B. Ananjeva and C. T. Ho. 2006a. A new cascade frog (Amphibia: Ranidae) from central Vietnam. Russian Journal of Herpetology. 13 (2): 155–163.

Orlov N. L., S. K. Dutta, H. V. Ghate and Y. Kent. 2006b. New species of *Theloderma* from Kon Tum Province (Vietnam) and Nagaland state (India) [Anura: Rhacophoridae]. Russian Journal of Herpetology. 13 (2): 135–154.

Orlov N. L. 2008. Description of a new species of *Rhacophorus* genus (Amphibia: Anura: Rhacophoridae) from Kon Cha Rang area (Gia Lai Province, Vietnam). Russian Journal of Herpetology. 15 (2): 133–140.

Orlov N. L., S. N. Nguyen and T. C. Ho. 2008. Description of a new species and new records of *Rhacophorus* genus (Amphibia: Anura: Rhacophoridae) with the review of amphibians and reptiles diversity of Chu Yang Sin National Park (Dac Lac Province, Vietnam). Russian Journal of Herpetology. 15 (1): 67–84.

Orlov N. L., N. A. Poyarkov, A. B. Vassilieva, N. B. Ananjeva, T. T. Nguyen, N. N. Sang and P. Geissler. 2012. Taxonomic notes on Rhacophorid frogs (Rhacophorinae: Rhacophoridae: Anura) of southern part of Annamite mountains (Truong Son, Vietnam), with description of three new species. Russian Journal of Herpetology 19 (1): 23–64.

Rahbek C. 1995. The elevational gradient of species richness: a uniform pattern? Ecography. 18 (2): 200–205.

Rao D.-Q. and D.-T. Yang. 1997. The variation in karyotypes of *Brachytarsophrys* from China with a discussion of the classification of the genus. Asiatic Herpetological Research. 7: 103–107.

Ron S. R. 2008. The evolution of female mate choice for complex calls in túngara frogs. Animal Behaviour. 76 (6): 1783–1794.

Rowley J. J. L., H. D. Hoang, D. T. T. Le, V. Q. Dau and T. T. Cao. 2010a. A new species of *Leptolalax* (Anura: Megophryidae) from Vietnam and further information on *Leptolalax tuberosus*. Zootaxa. 2660: 33–45.

Rowley J. J. L., D. T. T. Le, D. T. A. Tran, B. L. Stuart and H. D. Hoang. 2010b. A new tree frog of the genus *Rhacophorus* (Anura: Rhacophoridae) from southern Vietnam. Zootaxa. 2727: 45–55.

Rowley J. J. L., B. l. Stuart, S. j. Richards, S. Phimmachak and N. Sivongxay. 2010c. A new species of *Leptolalax* (Anura: Megophryidae) from Laos. Zootaxa. 2681: 35–46

Rowley J. J. L., B. l. Stuart, n. Thy and D. a. Emmett. 2010d. A new species of *Leptolalax* (Anura: Megophryidae) from northeastern Cambodia. Zootaxa. 2567: 57–68.

Rowley J. J. L., D. T. T. Le, H. D. Hoang, V. Q. Dau and T. T. Cao. 2011a. Two new species of *Theloderma* (Anura: Rhacophoridae) from Vietnam. Zootaxa. 3098: 1–20.

Rowley J. J. L., D. T. T. Le, D. T. A. Tran and H. D. Hoang. 2011b. A new species of *Leptolalax* (Anura: Megophryidae) from southern Vietnam. Zootaxa. 2796: 15–28.

Rowley J. J. L., H. D. Huy, V. Q. Dau, D. T. T. Le and T. T. Cao. 2012a. A new species of *Leptolalax* (Anura: Megophryidae) from central Vietnam. Zootaxa. 3321: 56–68.

Rowley J. J. L., D. T. A. Tran, H. D. Hoang and D. T. T. Le. 2012b. A new species of large flying frog (Rhacophoridae: *Rhacophorus*) from lowland forest in southern Vietnam. Jouranal of Herpetology. 46 (4): 480–487.

Royle A. J. and W. A. Link. 2005. A general class of multinomial mixture models for anuran calling survey data. Ecology. 86 (9): 2505–2512.

Smith M. A. 1921. New or little-known reptiles and batrachians from southern Annam (Indo-China). Proceedings of the Zoological Society of London. 91 (2): 423–440.

Smith M. A. 1924. New tree-frogs from Indochina and Malay Peninsula. Proceedings of the zoological society of London. 94 (1): 225–234.

Smith M. A. 1940. The amphibians and reptiles obtained by Mr. Ronald Kaulback in upper Burma. Records of the Indian Museum. 42 (3): 465–486.

Sterling E. J., M. M. Hurley and M. D. Le. 2007. Vietnam: A natural history. Yale University Press. 423 pp.

Stuart B. 1999. Amphibians and reptiles. Wildlife in Lao PDR: 1999 status report. World Conservation Union**:** 43–56.

Stuart B., S. Phimmachak, S. Seateun and N. Sivongxay. 2012. A new *Leptobrachium* (Anura: Megophryidae) from the highlands of southeastern Laos. Zootaxa. 3155: 29–37

Stuart B. L. and D. A. Emmett. 2006. A collection of amphibians and reptiles from the Cardamom mountains, southwestern Cambodia. Fieldiana: Zoology. 109: 1–27.

Stuart B. L., K. Sok and T. Neang. 2006. A collection of amphibians and reptiles from Hilly Eastern Cambodia. The Raffles Bulletin of Zoology. 54 (1): 129–155.

Stuart B. l., J. J. L. Rowley, D. T. A. Tran, D. T. T. Le and H. D. Hoang. 2011. The *Leptobrachium* (Anura: Megophryidae) of the Langbian Plateau, southern Vietnam, with description of a new species. Zootaxa. 2804: 25–40.

Taylor E. H. 1962. The amphibian fauna of Thailand. The Univerisity of Kansas Sicence Bulletin. XLIII (8): 265–599.

Tran D. T. A., Q. K. Le, K. V. Le, T. N. Vu, T. Q. Nguyen, W. Böhme and T. Ziegler. 2010. First and preliminary frog records (Amphibian: Anura) from Quang Ngai Province, Vietnam. Herpetology Notes. 3: 111–119.

Tran D. T. A., T. T. Nguyen, T. M. Phung, T. Ly, W. Boehme and T. Ziegler. 2011. Redescription of *Rhacophorus chuyangsinensis* Orlov, Nguyen & Ho, 2008 (Anura: Rhacophoridae) based on new collections from new south Vietnamese provincial records: Lam Dong and Khanh Hoa. Revue suisse de Zoologie. 118 (3): 1–9.

Trepanier T. L., A. Lathrop and R. W. Murphy. 1999. *Rhacophorus leucomystax* in Vietnam with acoustic analyses of courtship and territorial calls. Asiatic Herpetological Research. 8: 102–106.

Wagh S. M. and D. A. Deshpande. 2013. Essentials of physics: Volume II. PHI Learning Private Limited, Delhi. 671 pp.

Wells K. D. 2007. The ecology and behavior of amphibians. University of Chicago. 1148 pp.

Wildenhues M. J., M. F. Bagaturov, A. Schmitz, D. T. A. Tran, R. Hendrix and T. Ziegler. 2011. Captive management and reproductive biology of Orlov's Treefrog, *Rhacophorus orlovi* Ziegler & Köhler, 2001 (Amphibia: Anura: Rhacophoridae), including larval description, colour pattern variation and advertisement call. Der Zoologische Garten. 80: 287–303.

Yu G., M. Zhang and J. Yang. 2013. Molecular evidence for taxonomy of *Rhacophorus appendiculatus* and *Kurixalus* species from northern Vietnam, with comments on systematics of *Kurixalus* and *Gracixalus* (Anura: Rhacophoridae). Biochemical Systematics and Ecology. 47: 31–37.

Ziegler T. 2002. Die Amphibien und Reptilien eines Tieflandfeuchtwald-Schutzgebietes in Vietnam. Natur un Tier - Veglag GmbH. 342 pp.

Ziegler T., T. Hartmann, K. V. d. Straeten, D. Karbe and W. Böhme. 2008. Captive breeding and larval morphology of *Tylototriton shanjing* Nussbaum, Brodie & Yang, 1995, with an updated key of the genus *Tylototriton* (AmphibiaL Salamandridae). Der Zoologishche Garten. 77: 246–260.

Ziegler T. and T. Q. Nguyen. 2008. The amphibian and reptilian breeding station at Hanoi. WAZA Magazine. 9: 10–14.

Ziegler T. and T. Q. Nguyen. 2010. New discoveries of amphibians and reptiles from Vietnam. Bonn Zoological Bulletin. 57 (2): 137–147.

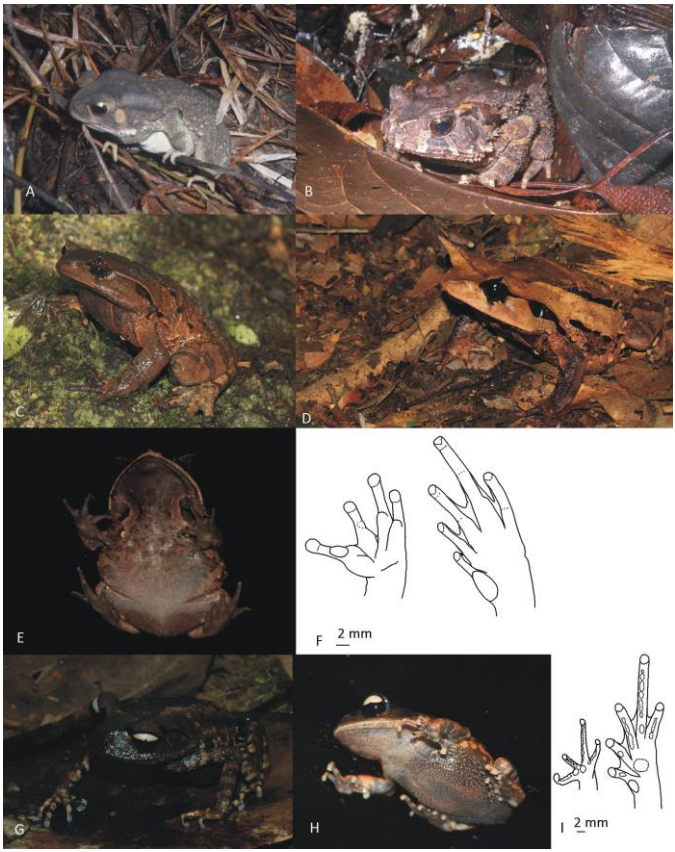

Plate 1. Genera *Duttaphrynus, Ingerophrynus, Brachytarsophrys,* and *Leptobrachium.*
A: *Duttaphrynus melanostictus*; B: *Ingerophrynus galeatus*;
C-F: *Brachytarsophrys intermedia* (C: male; D: female; F: webbing formula); G-I: *Leptobrachium leucops.*

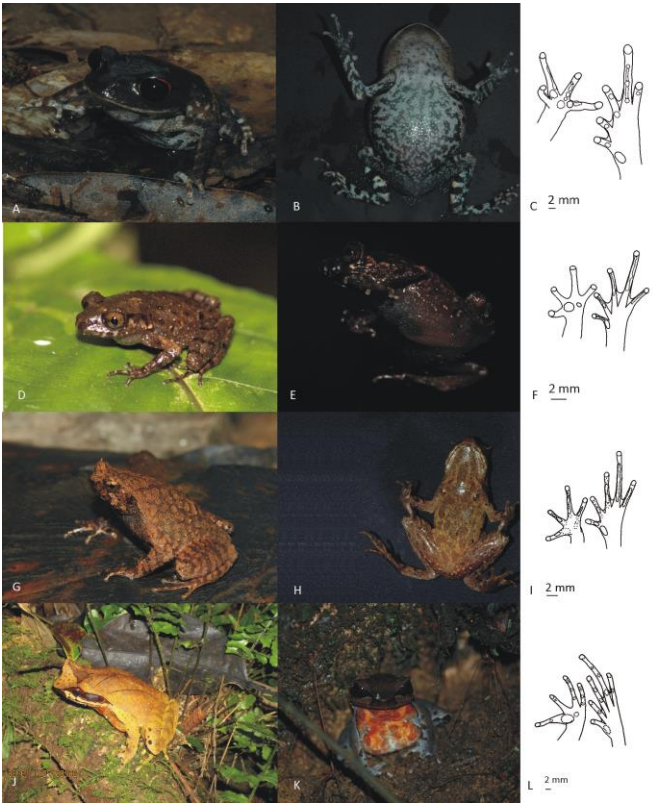

Plate 2. Genera *Leptobrachium, Leptolalax, Ophryophryne,* and *Xenophrys*
A-C: *Leptobrachium pullum*; D-F: *Leptolalax bidoupensis*;

G-I: *Ophryophryne hansi*; J-L: *Xenophrys major*

Plate 3. Genera *Calluella, Kaloula pulchra,* and *Microhyla.*
A-B: *Calluella guttulata*; C: *Kaloula pulchra*; D: *Microhyla annamensis*; E: *M. heymonsi*; F: *M. pulchra*; G: *M*. sp1; H: *M*. sp.2

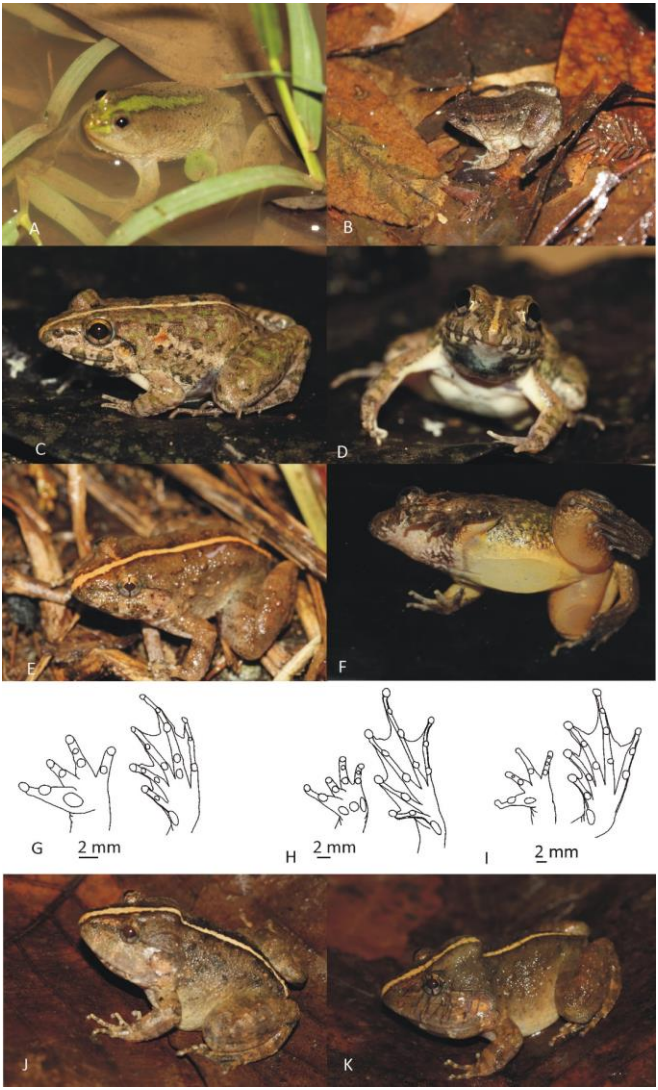

Plate 4. Genera *Occidozyga, Fejervarya,* and *Limnonectes*.
A: *Occidozyga lima*; B: *O. martensii*; C-D & G: *Fejervarya limnocharis*; E-F, & H: *Limnonectes poilani*; J-K, & I: *Limnonectes dabanus*.

Plate 5. Genus *Hylarana*
A-C: *Hylarana attigua*; D-F: *H. milleti*; G-I: *H. montivaga*;

J-L: *H. nigrovittata*

Plate 6. Genera *Rana, Odorrana, Chiromantis, Feihyla,* and *Kurixalus*.

A: *Rana johnsi*; B-C: *Odorrana gigatympana*; D-G: *O. Graminea* (D, E: males; G: female); G-H: *Chiromantis nongkhorensis*; I-L: *Feihyla palpebralis*; M-O: *Kurixalus baliogaster*.

Plate 7. Genera *Polypedates, Raorchestes,* and *Rhacophorus.*
A: *Polypedates* cf. *mutus*; B-C: *P. megacephalus*; D-F: *Raorchestes gryllus*; G-I: *Rhacophorus annamensis*; J-L: *R. vampyrus* (J: adult male; K: juvenile).

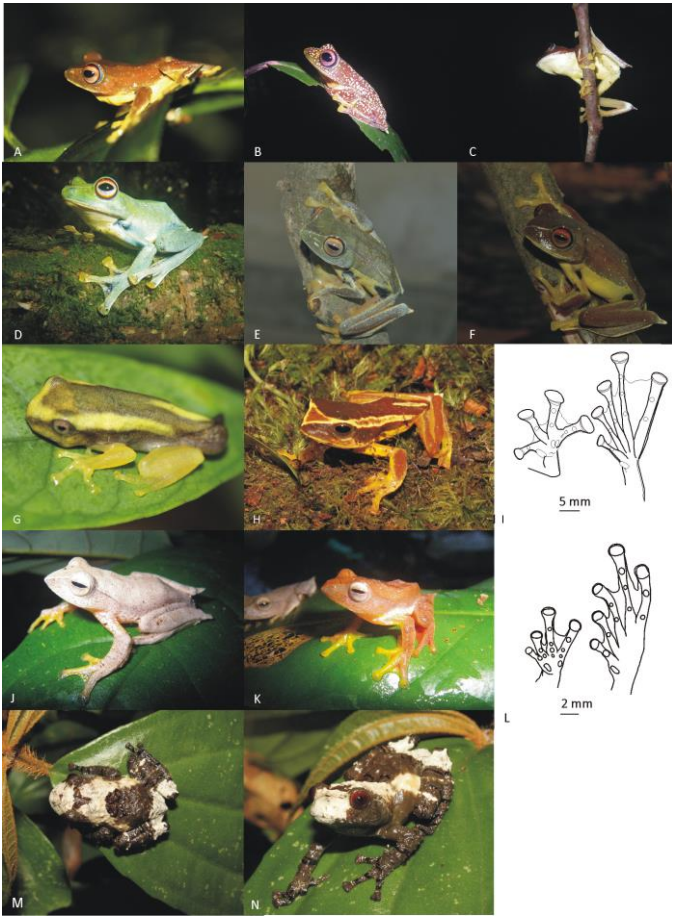

Plate 8. Genera *Rhacophorus* and *Theloderma.*
A-G: *Rhacophorus calcaneus* (A-C, E-F: males; D: female; G: metamorph, H: juvenile); H-I: *R. robertingeri*; J-K: *Theloderma asperum.*

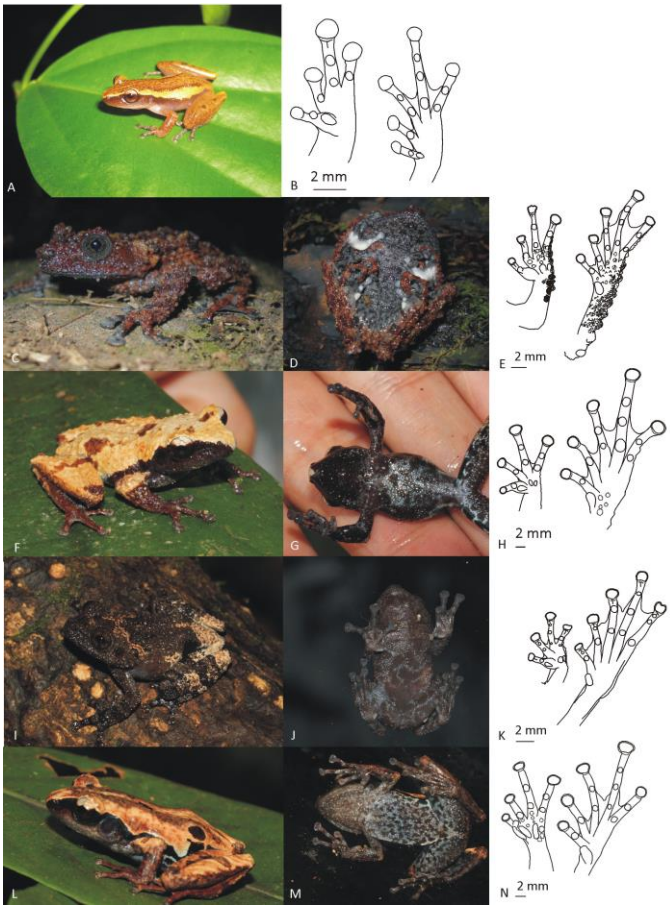

Plate 9. Genus *Theloderma*.
A-B: *T. bambusicolum*; C-E: *T. gordoni*; F-H: *T. palliatum*; I-K: *T. stellatum*; L-M: *T. truongsonense*.

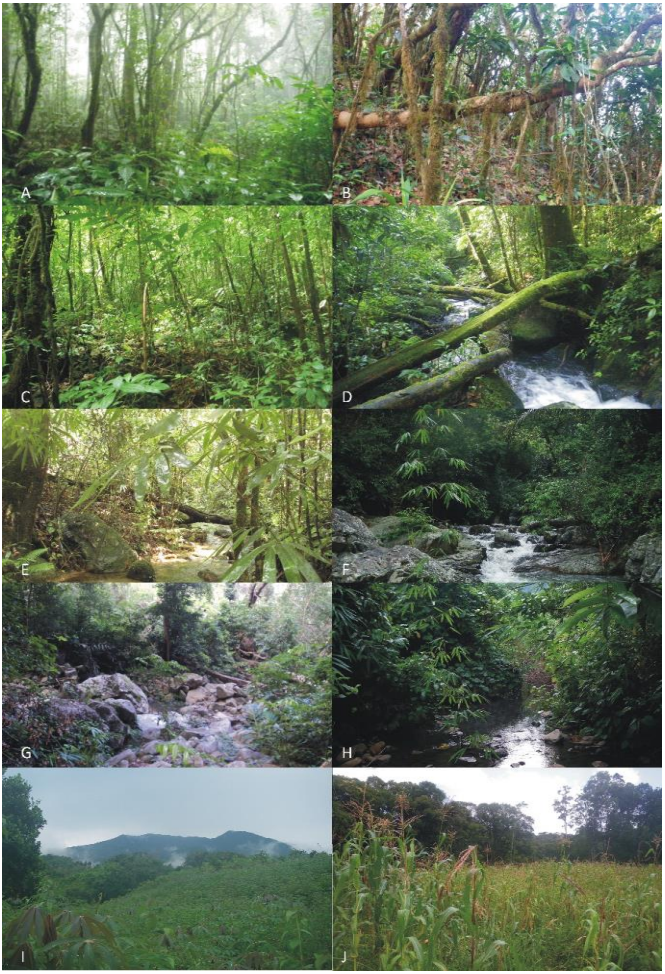

Plate 10. Types of forests in the Langbian Plateau.
A: Cloud forest in TD NR; B: Cloud forest in BDNB NP; C: evergreen forest in BDNB NP (1500 m elev.); D: Stream in evergreen forest in BDNB NP (1800 m elev.); E Stream in mixed forest of hard wood and bamboo in CYS NP (900 m elev.); F: Stream in mixed forest of hard wood and bamboo in PB NP (700 m elve.); G: Stream in mixed forest of small hard wood and bamboo in SLSM; H: A channel in mixed forest of small hard wood and bamboo in SLSM; I & J: cultivated areas in TD NR.

Plate 11. Microhabitats using by anurans in the Langbian Plateau. A: Shallow water in CYS NP; B: A rain puddle in TD NR; C: Leaf litter and fallen trees on the ground; D: Small shrubs nearby a swallow water in CYS NP; E & F: Vegetation and grass near to corn farm in SLSM; G–I: Small streams with grass, small trees and shrubs along the banks in BDNB NP; J & K: Rocks along banks of stream in PB NP & SLSM; L: Rocky crevice in SLSM (above) and hole in bank along stream in BDNB NP (below).

Plate 12. Amplexus ativities in amphibans from the Langbian Plateau.

A: *Leptobrachium leucops*; B: *Leptobrachium pullum*; C: *Limnonectes poilani*; D: *Calluella guttulata*; E & F: *Polypedates megacephalus*; G–I: *Rhacophorus annamensis*; J: *Raorchestes gryllus*.

Plate 13. Color pattern in *Raorchestes gryllus.*

APPENDIX 1. PUBLICATIONS OF KEY PART OF THE DISSERTATION

Rowley JJL, Le DTT, Tran DTA, Stuart BL, Hoang HD. 2010. A new tree frog of the genus *Rhacophorus* (Anura: Rhacophoridae) from southern Vietnam. Zootaxa 2727:45−55.

Rowley JJL, Le DTT, Tran DTA, Hoang HD. 2011. A new species of *Leptolalax* (Anura: Megophryidae) from southern Vietnam. Zootaxa 2796:15−28.

Stuart BL, Rowley JJL, Tran DTA, Le DTT, Hoang HD. 2011. The *Leptobrachium* (Anura: Megophryidae) of the Langbian Plateau, southern Vietnam, with description of a new species. Zootaxa 2804:25−40.

Tran, D. T. A., Nguyen, T. T., Phung, T. M., Ly, T., Boehme, W. & Ziegler, T. (2011). Redescription of *Rhacophorus chuyangsinensis* Orlov, Nguyen & Ho, 2008 (Anura: Rhacophoridae) based on new collections from new south Vietnamese provincial records: Lam Dong and Khanh Hoa. Revue suisse de Zoologie 118, 1−9.

Rowley, J. J. L., D. T. A. Tran, D. T. T. Le, H. D. Hoang and R. Altig. 2012. The strangest tadpole: the oophagous, tree-hole dwelling tadpole of *Rhacophorus vampyrus* (Anura: Rhacophoridae) from Vietnam. Journal of Natural History 46 (47−48): 2969−2978.

APPENDIX 2. CURRICULUM VITAE

Name:	Tran, Thi Anh Dao
Date of birth:	13.03.1974
Place of birth:	Sai Gon (now Ho Chi Minh City), Vietnam
Nationality:	Vietnamese
Address in Vietnam:	The University of Science, Ho Chi Minh City, Vietnam Faculty of Biology 227 Nguyen Van Cu, District 5, Ho Chi Minh City, Vietnam
Address in Germany:	The Zoologisches Forschungsmuseum Alexander Koenig Herpetology Section Adenaueralle 160, 53113 Bonn
Email:	ttadao.hcmuns@gmail.com

Education and Training

1992 - 1994	Studied at Forestry and Aquaculture University, Vietnam
1994−1997	Studied at University of Natural Science Ho Chi Minh City, Vietnam (Bachelor of Science)
1999−2002	Studied at University of Natural Science Ho Chi Minh City, Vietnam (M. Sc. Animal Physiology) Thesis title: "*Efficiency of using the CMS (Concentrate Molasses Solution) as a material of artificial food for freshwater fish in aquaculture*"

2004	Training course on Wetland Ecology and management in the Lower Mekong Basin (at Mahidol University, Thailand).
10/2009−2013	Study at University of Bonn, Germany (Faculty of Mathematic and Natural Science).

Employment

1998−2003	Lecturer assistant at Department of Zoology and Animal Physiology, Faculty of Biology, University of Natural Science Ho Chi Minh City, Vietnam.
2003−2013	Lecturer at Department of Zoology and Animal Physiology, Faculty of Biology, University of Natural Science Ho Chi Minh City, Vietnam. Resposibility in subjects: “Labwork of General Biology” (for the first class students) and “Labwork of Vertebrates” (for the second class students).

Publications and presentation

Tran DTA, Le QK, Le KV, Vu TN, Nguyen TQ, Böhme W, Ziegler T. 2010. First and preliminary frog records (Amphibian: Anura) from Quang Ngai Province, Vietnam. Herpetology Notes 3:111−119.

Rowley JJL, Le DTT, Tran DTA, Stuart BL, Hoang HD. 2010. A new tree frog of the genus *Rhacophorus* (Anura: Rhacophoridae) from southern Vietnam. Zootaxa 2727:45−55.

Rowley JJL, Le DTT, Tran DTA, Hoang HD. 2011. A new species of *Leptolalax* (Anura: Megophryidae) from southern Vietnam. Zootaxa 2796:15−28.

Stuart BL, Rowley JJL, Tran DTA, Le DTT, Hoang HD. 2011. The *Leptobrachium* (Anura: Megophryidae) of the Langbian Plateau, southern Vietnam, with description of a new species. Zootaxa 2804:25−40.

Tran, D. T. A., Nguyen, T. T., Phung, T. M., Ly, T., Boehme, W. & Ziegler, T. (2011). Redescription of *Rhacophorus chuyangsinensis* Orlov, Nguyen & Ho, 2008 (Anura: Rhacophoridae) based on new collections from south Vietnamese provincial records: Lam Dong and Khanh Hoa. Revue suisse de Zoologie 118, 1−9.

Wildenhues, M. J., Bagaturov, M. F., Schmitz, A., Tran, D. T. A., Hendrix, R. & Ziegler, T. (2011). Captive management and reproductive biology of Orlov's Treefrog, *Rhacophorus orlovi* Ziegler & Köhler, 2001 (Amphibia: Anura: Rhacophoridae), including larval description, colour pattern variation and advertisement call. *Zool. Garten N.F.* 80, 287−303.

Rowley, J. J. L., D. T. A. Tran, D. T. T. Le, H. D. Hoang and R. Altig. 2012. The strangest tadpole: the oophagous, tree-hole dwelling tadpole of *Rhacophorus vampyrus* (Anura: Rhacophoridae) from Vietnam. Journal of Natural History 46 (47−48): 2969−2978.

Rowley, J. J. L., D. T. A. Tran, H. D. Hoang and D. T. T. Le. 2012. A new species of large flying frog (Rhacophoridae: Rhacophorus) from lowland forest in southern Vietnam. Jouranal of Herpetology 46 (4): 480−487.

Participate the 5th Asia Herpetological Conference in Chengdu, Sichuan, China (2−4 June 2012): "Amphibian communities in Langbian Plateau, southern Vietnam". (Oral presentation).